D3.6: Report on Drones/multicopters platform implemented and deployed

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Abstract:	The report contains details regarding the preparation of the drone flight campaigns in the selective areas in Cyprus and Lithuania and the generation of Very-High-Resolution (VHR) RGB images of the collected data. Details were given regarding the implementation of the automated processing flow receiving the aforementioned results, the prerequisite steps that were necessary and were scheduled before the initiation of the campaigns, and the output results, including the methods of the evaluation of image and georeferencing quality.

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List of Abbreviations and Acronyms	
VHR	Very High Resolution
EO	Earth Observation
LCLU	Land Cover/Land Use
EFA	Ecological Focus Areas
GCP	Ground Control Points
UAV	Unmanned Aerial Vehicle
ROI	Region of Interest
UI	User Interface
USB	Universal Serial Bus
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984
QGIS	Quantum Geographic Information System
RTK	Real-Time Kinematic
GPS	Global Positioning System
AOI	Area of Interest
EASA	European Aviation Safety Agency
EC	European Commission
GDPR	General Data Protection Regulation
ESA	European Space Agency
DWH	Data Warehouse
CAP	Common Agricultural Policy
DAP	Data Access Portfolio
ha	hectares
NTUA	National Technical University of Athens
LTCP	Lavrion Technological Cultural Park
NOTAMs	Notices to Airmen
DSM	Digital Surface Model
EXIF	Exchangeable image file format
FFT	Fast Fourier Transform
COG	Cloud optimised GeoTIFF
HTTPS	Hypertext Transfer Protocol Secure
SH	Sentinel Hub
RMSE	Root Mean Square Error
BYOC	Bring Your Own Cloud Optimised GeoTIFF

1. Introduction

1.1 Purpose of this document

This document belongs to a group of deliverables that aim to showcase the implementation aspects that were fulfilled until the first 24 months of the project for the preparation of the alpha versions of all the DIONE's components. Within the overall solutions that are expressed through the DIONE's ecosystem, (Figure 1) this document focuses on the first component denoted as Earth Observation (EO) component and in specific on one of the demonstrated solutions, which is the generation of successful drone flights and the generation of accurate, georeference Very-High-Resolution (VHR) images. The developed drone platform is planned to be used in both pilot demonstrations in the jurisdictions of the National Paying Agency under the Ministry of Agriculture of the Republic of Lithuania (NMA)[1] and Cyprus Agricultural Payments Organisation (CAPO)[2], with a successful outcome to be the real assistance of the collected data to the rest of the EO component data, e.g. Sentinel-2 images and the VHR complementary satellite data provided by the ESA Data Warehouse Mechanism, and generated agricultural products, such as the identification of the Ecological Focus Areas (EFAs), and the Land Cover/Land Use (LCLU) and any other potential marker. The maximum value of this drone platform solution will be a significant improvement in spatial accuracy and thematic consistency of the aforementioned products, giving accurate estimations in 1m or less and overcoming the additional limitations that optical sensors have, which is the inability to penetrate clouds.

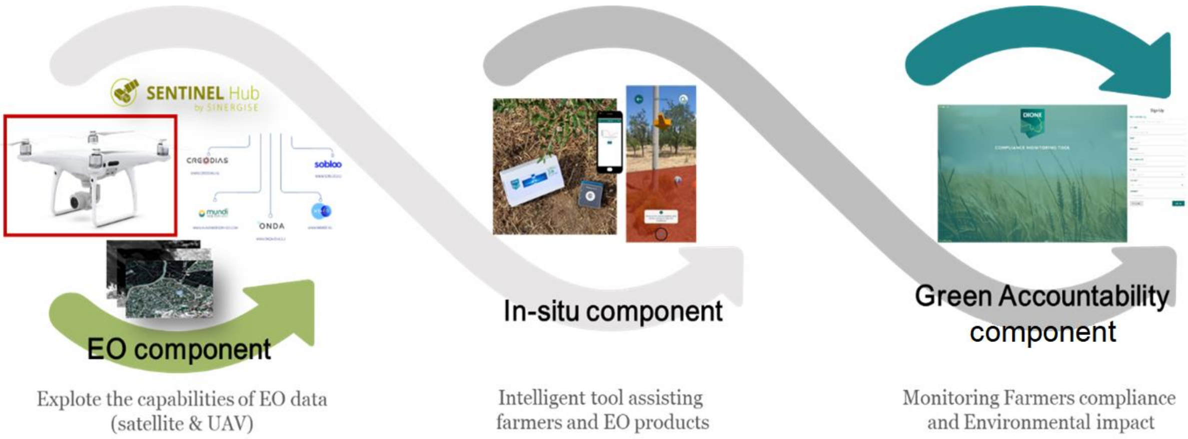


Figure 1: Tools that have been used and developed, comprising the DIONE ecosystem. Highlighted with the red box is the component that will be analysed in the current document.

Eventually, through this deliverable, a brief overview will be given on the preparation phase and the organisation of test flights to ensure that the whole system is functional for the real demonstrations. Additional descriptions and a co-design process will be depicted, enlightening the collaborative nature of this task. Under this concept, definitions of pilot areas for both Lithuania and Cyprus were identified in order to meet users' requirements as well as the number of repetitions and specific dates, where the flights were scheduled to take place. The subsequent analysis is given for the demonstration of the flight campaigns, the collection of the ground control points (GCPs) and the 3D reconstruction of the image orthomosaic. Finally, obstacles to the abovementioned activities due to the weather conditions and the adopted solutions to overcome these limitations are also presented. A

[1] https://www.nma.lt/index.php/support/direct-payments/696

[2] http://www.capo.gov.cy/capo/capo.nsf/index_gr/index_gr?OpenDocument

complementary step of this analysis is to reveal the processing flow that was developed for the integration of the drone imageries with the overall EO data processing cycle.

1.2 Intended readership

This deliverable is intended for public use, aiming to inform relevant stakeholders on the drone flight campaigns that were conducted, and under which process the drone initial images were processed in order to generate the VHR orthomosaic products. In addition, from a general dissemination strategy point of view, it may also be useful for other H2020 projects.

1.3 Relationship with other deliverables in DIONE

The current report is built based on the requirements analysis that was presented in deliverable D3.1 "Analysis of the Software specifications", submitted in M8, where a preliminary analysis was conducted regarding the hardware and software specifications with which the DIONE Unmanned Aerial Vehicle (UAV) platform was designed, and successful and secure drone flights that will be presented in the following chapters were implemented.

1.4 Structure of this Document

This document is organised into 7 chapters, whose description is summarised through the following bullet points.

- Chapter 1 - Introduction: containing a short intro and overview of this document, and its relation with any former deliverable(s).
- Chapter 2 - Drone platform and workflow: Describing the design architecture of the drone platform consisting of the on the field processes of images' collection including the hardware-software components and the generation of the georeferenced image orthomosaics.
- Chapter 3 - Preparation phase: Illustrating all the offline organisation details that had to be arranged for the finalisation of the regions of interest, where the drone flights were taken place, and the number of repetitions, and the specific dates, the necessary steps for the collection of the ground control points specifying as well the characteristics of the equipment that will be used. Additional information is given regarding the risks that the drone operator had to consider in terms of the COVID-19 pandemic. Last but not least, the chapter describes the arrangement of a test flight in outdoor conditions, ensuring that the processing flow was well-defined and the operator is able to generate an accurate and high-quality result, eliminating any potential obstacle that could be faced during the official drone flights.
- Chapter 4 - Drone flight campaigns: Illustrating the conduction of the drone flight campaigns that were conducted in the regions of interest in Cyprus and Lithuania
- Chapter 5 – Present the evaluation methods that were conducted ensuring the provision of orthomosaic VHR products at high quality.
- Chapter 6 - Integration with the EO component's data processing cycle: In line with the analysis that was given in deliverable 3.4, in this document, a short presentation is given of the processing chain that was developed for the image transformation and ingestion to the whole EO solution.
- Chapters 7 and 8 – The final chapters complement the abovementioned analysis, illustrating how the implemented solutions fulfil the requirements and specifications and the DIONE's overall ambition, as they have been defined in deliverables D2.1 and D3.1, and concluding with any recommendations related to future improvements.

2. Drone platform and workflow

2.1 Overview of the designed drone workflow and construction of VHR images

The following sections will attempt to give a thorough view regarding the individual steps that comprise the conduction of the drone flights and the synthesis of the 2D VHR orthomosaics. The descriptions will be in line with the UAV platform design as it was described within the D3.1 and will mention any additional information, change and simplification that was implemented in the operational process. Figure 2 depicts the total workflow where the collected data of the flight process are exploited to extract orthomosaics of the areas of interest.

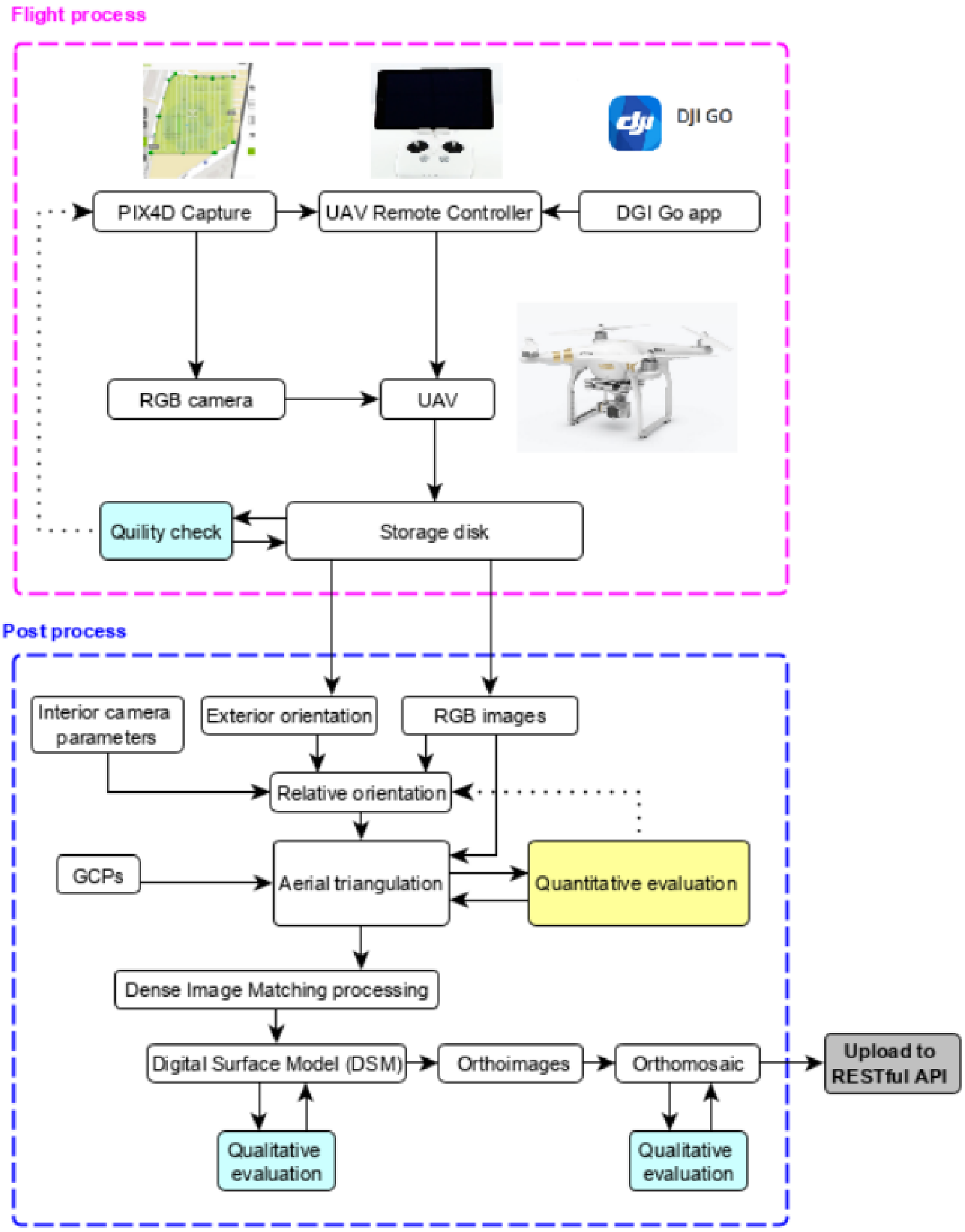


Figure 2: Total workflow where the collected data of the flight process are exploited to extract orthomosaics of the areas of interest

2.1.1 Design the flight process workflow

The architecture design of the Unmanned Aerial Vehicle system is mainly based on three basic components: i) the aerial unmanned platform (UAV), ii) the UAV pilot's remote controller and iii) a mobile/tablet device, in which the corresponding software for controlling and mission planning is installed. Table 1 describes the hardware and software components that contribute to the flight process, adding any further information that was gained from the operational deployment of the UAV platform.

Table 1: Components of the UAV platform that contribute to the flight process

UAV	In the context of DIONE, an unmanned quadcopter platform is utilised. Some characteristics of the UAV are: i) GNSS/GPS receiver, ii) georeference, iii) extraction of georeferenced images embodying the exterior information of each image as *.EXIF format, etc.
Pilot's Remote Controller	The Pilot's remote controller is for flying and controlling the UAV. It presents all the information regarding communication and navigation, contains the control UI for the UAV and handles the flight planning.
Mobile/tablet device	It is responsible for communication and navigation, containing the control User Interface (UI) for the UAV and handles the flight planning. In this device, the corresponding software for controlling (DJI Go app, Ctrl+DJI plugin) and mission planning (Pix4Dcapture) are installed.
Camera	A high-resolution RGB camera and a gimbal exist at the payload of the UAV.

Determining the aforementioned components, a process of taking aerial photos with the UAV platform using the drone can be carried out. In particular, before the initiation of the flight mission, the firmware on the aircraft and the remote controller has to be properly configured, establishing the communication to establish the necessary communication between the two parts. The software "DJI Go app" (https://play.google.com/store/apps/details?id=dji.pilot), as well as the "Pix4Dcapture" (https://www.pix4d.com/product/pix4dcapture) and its companion app "Ctrl+DJI" (https://play.google.com/store/apps/details?id=com.pix4d.plugindji), are open accessed software, as our will was to develop a viable solution that could be easily applied and after the end of the project. The "DJI Go app" is responsible to set parameters concerning the i) flight heights and failsafe, ii) battery critical warnings, iii) video transmission channels and iv) gimbal camera setting (brightness, contrast, etc). The "Pix4Dcapture" allows to set parameters concerning automatic flight plan missions, including the execution of polygon flight plans or circular flight plans. The "Ctrl+DJI" is required by "Pix4Dcapture" for the latter to establish a link with the UAV through the USB interface between the mobile/tablet device and the UAV Remote Controller. It should be noted that the two controlling software, e.g. DJI Go and Ctrl+DJI require exclusive access to the USB interface of the mobile/tablet device in order to communicate with the UAV Remote Controller.

The connection of the aforementioned components is also revealed in Figure 2. Additionally, Figure 3*Figure 4* and Figure *5* depict respectively: i) the companion app for Pix4Dcapture (Ctrl+DJI), ii) the home screen of Pix4Dcapture in which we can create new missions or navigate to existing ones, iii) an example project containing its related missions, iv) an example of a flight mission through the Pix4Dcapture along with several mission parameters (camera information, percentage overlap, heights, etc).

During the flight the following issues should be taken into account:

- Weather conditions
- Safety conditions
- Available battery power and duration of the UAV flight

Especially strong winds may have an impact on the clarity of the pictures captured during the flight, due to strong vibrations. Moreover, strong winds may reduce the flight time of each battery. Section 5 gives a thorough view of the procedures that were applied as evaluation processed regarding the collected images the geolocation accuracy of the resulting orthomosaic images and the effects that were resulted from the intense weather conditions, and the methods applied to address these challenges.

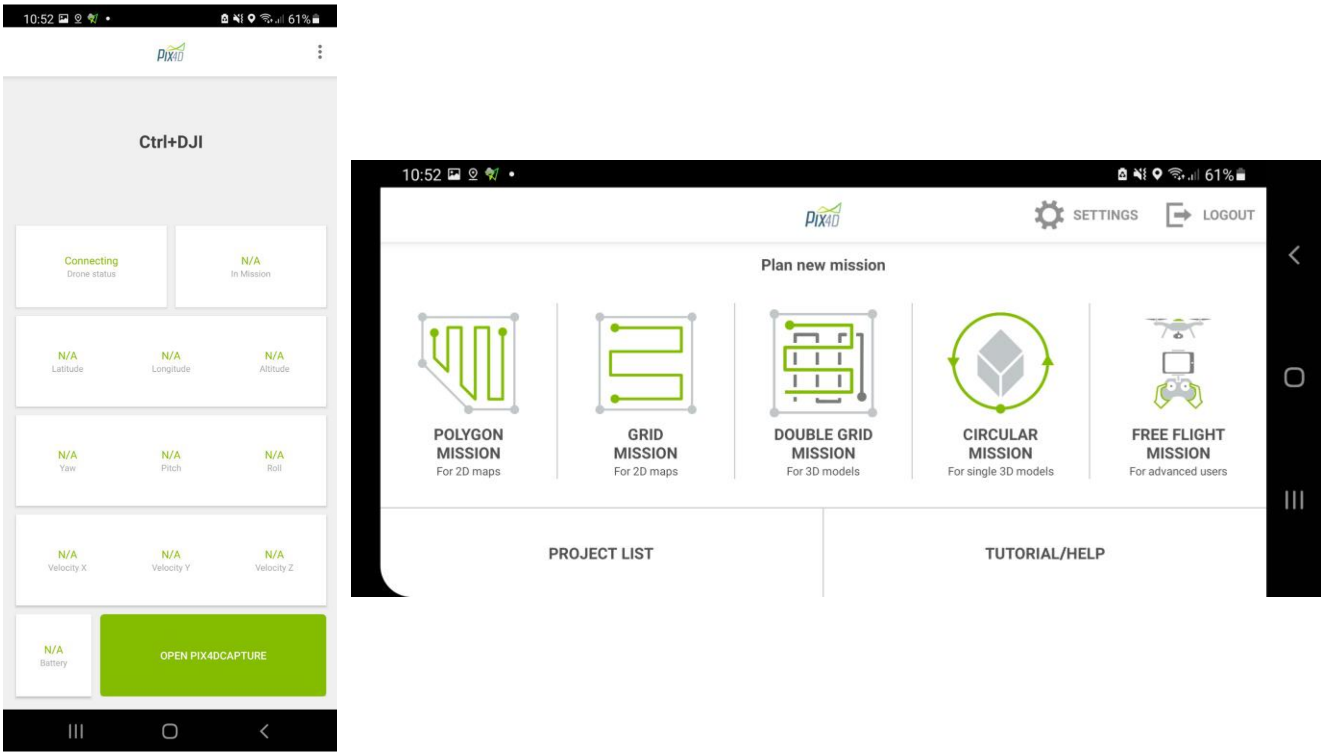


Figure 3: Left-side image: Ctrl+DJI application; Right-side image: Pix4Dcapture home screen

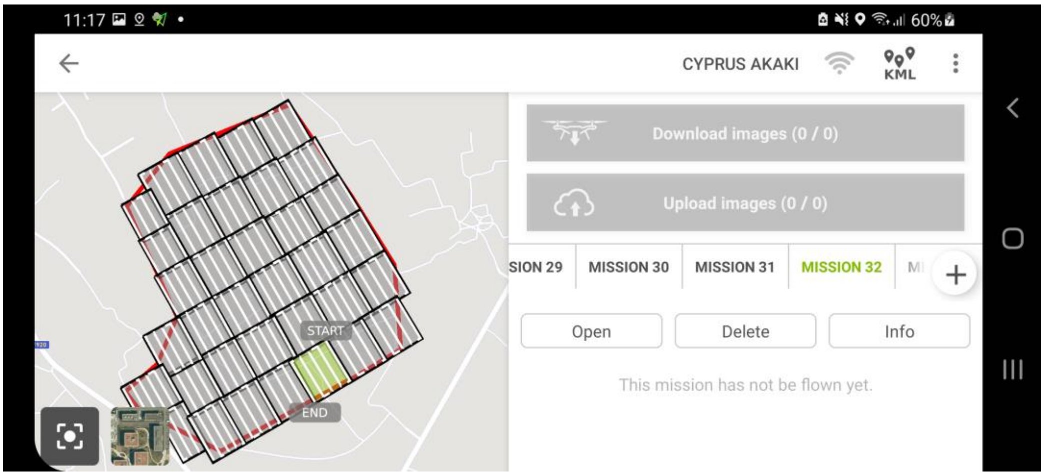


Figure 4: A collection of related missions (project) shown on the map

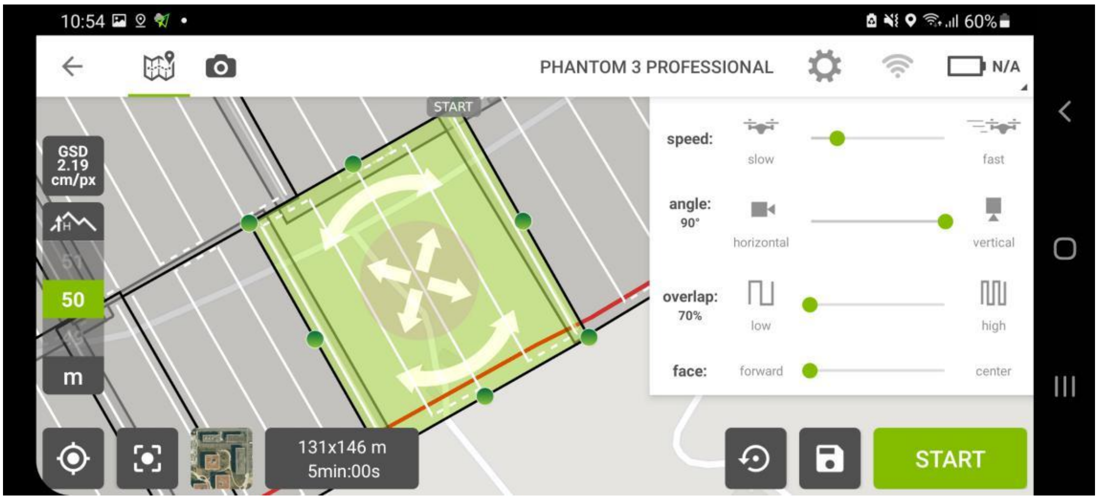


Figure 5: An opened mission along with its parameters.

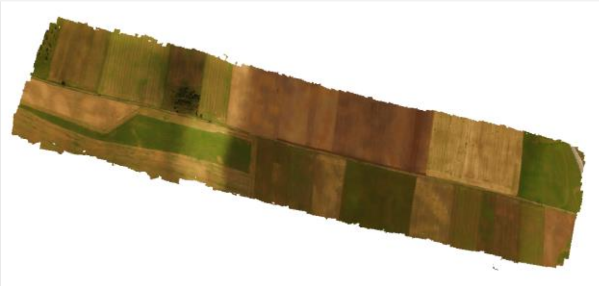
2.1.2 Generation of image orthomosaics

After the collection of the necessary drone images, the next stage is to process the aerial photos using photogrammetry techniques to produce a 3D model reconstruction and a 2D RGB image orthomosaic. For this process, the Agisoft Metashape professional software is used, along with the following steps that are also illustrated in the Post-process section of Figure 2. Before the 3D model reconstruction, it is critical to calibrate the camera so that the model produced will have a high level of accuracy. If an image is captured with a different camera, this step is essential. In our case, and for the purposes of DIONE project, images were collected by using only one camera, the default that is installed in the drone.

- **File Upload:** At this point, the overall dataset with the collected drone images is imported to the Agisoft Metashape software.
- **Relative orientation and Image alignment:** Homologous key points are detected and matched on overlapping images, leading to an estimate of the external camera parameters. Before performing image alignment several accuracy options can be selected at this step: selecting "High" accuracy, Agisoft Metashape uses the full resolution photo, "Medium" setting causes image downscaling by a factor of 4 (2 times by each side), at "Low accuracy" source files are downscaled by a factor of 16, and "Lowest" value means further downscaling by 4 times more. "High" accuracy is selected for best results.
- **Aerial triangulation – Buddle adjustment:** In this step, includes the processes that are responsible for the determination of the correct position and orientation of each image in a series of aerial images so they can be compiled into a map. For this case and as it can be seen in Figure 2, the collected Ground Control Points (GCPs) are imported in plain text data format. Before using of GCPs, the necessary transformations were performed in the coordinated system, to match the corresponding UTM of each area. For the Lithuanian use case, conversions were implemented from LKS94/Lithuania TM (EPSG: 3364) to the WGS84 UTM 34N (EPSG: 32634) and for Cyprus in UTM 36N (EPSG: 32636).
- **Dense image matching processing (Build dense point cloud):** By the use of a dense image matching algorithm, the software generates a dense point cloud, whose final cardinality depends on the chosen settings: "Ultra-high" setting implies the processing of full-size images, whereas with "High", "Medium", "Low" and "Lowest" images are downscaled before the dense matching procedure by a factor 50%, 25%, 12.5% and 6.75%, respectively. "Ultra-high" is selected.

- **Building mesh**: In this step, textured triangulated meshes are obtained from dense point clouds.
- **Construction of the image 2D orthomosaic**: In this step, the whole object surface is textured in the orthographic projection. In addition, Agisoft Metashape enables to perform orthomosaic seam-line editing for better visual results.
- **Exclude rough edges**: After the generation of the 2D orthomosaic, it is usually identified some rough edges in the boundaries of the orthomosaics, produced by the Metashape. To exclude these areas, the raster clipping procedure offered by the open-accessed software of QGIS is used. An example of the aforementioned artefact is shown in Table 2.

Table 2: Example reveals the exclusion of the rough edges as they are initially produced by the Agisoft Metashape software.

Initial orthomosaic with rough edges	Final orthomosaic after the raster clipping
	

2.2 Technical Summary

With the aforementioned processing flows to be determined in the corresponding chapters, the process of taking RGB aerial photos with the UAV using the drone was carried out. Whereas with the acquired photos and the necessary GCPs a 3D model generation and the production of image orthomosaics could be achieved. In the following table, a brief representation of the specifications of the equipment and the parameters of the autopilot track mode is given.

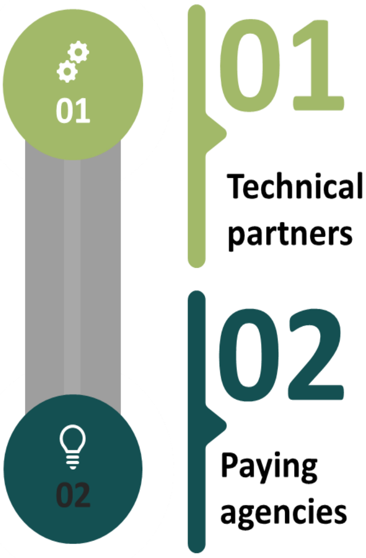
Table 3: Hardware and Software equipment specifications and parameters.

Parameters	Description
Ground Control Points	RTK GPS receiver: Topcon-GR3 GPS
Drone type	Aircraft DGI Phantom 3 Professional
Camera	1/2.3" CMOS Effective pixels: 12.4 M (total pixels: 12.76 M)
Flight speed	5m/s
Adjustable Aperture	f/2.8
Software track autopilot	DJI GO and Pix4Dcapture
Required Operating Systems	Android version 10 or later
Device	Samsung s20+
Required operating systems	Android 4.1.2 or later
Flight duration	approx. 125-250 minutes per AOI
Flight altitude	50m above takeoff position
Image resolution	4000 pixels (Width) × 3000 pixels (Height)
Spatial resolution	2.2 cm/px
Images' overlap	70%

3. Preparation phase

3.1 An iterative & collaborative process

The preparation of the drone flight campaigns to collect RGB images with the spatial resolution below the one-meter was a process that was identified in order to meet the needs of the project and the users. This way, the objectives that are going to be described in the following chapters were determined through a collaborative process between the two Paying Agencies that are involved in the DIONE project (e.g. NPA and CAPO) and the corresponding technical partners (i.e. ICCS). The overall procedure is illustrated in the following steps.



1) Being aligned with the regulations that concern the proper use of Unmanned Aerial Vehicles (UAVs)/drones, following the updated regulation schema as it was formulated by the European Commission (EC) and the EASA (European Aviation Safety Agency).
2) Definition of the regions of interest (ROIs), where the drone flights were scheduled to be conducted according to the spatiotemporal availability of the VHR data and crop and land cover types that could be captured within those areas.
3) Definition of the number of repetitions and the exact dates according to the phenological stages of the majority of the identified crop types.
4) Enhancing the positional and spatial accuracy of the generated orthomosaics from the collected drone image through ground control points (GCPs).
5) Considering the COVID-19 pandemic, proper arrangements had to be fulfilled to ensure that our missions would be aligned with the respective local restrictions.
6) Finally, testing of the drone platform prior to the conduction of the official flight campaigns and the construction of the drone orthomosaic was performed, making sure the designed solution was properly formulated, addressing any potential challenge.

The 2, 3 and 4 bullet points were defined through an iterative process, as all of them could dynamically change according to the weather conditions (e.g. drones are incapable to fly with cloudy and rainy weather) and the COVID-19 stage each time considering the daily number of affected citizens both in the country that the flights are going to be taken place and the country of the drone operator and the lockdown restrictions. The first case is a phenomenon that more commonly seemed to appear in Lithuania regions, due to its unstable weather conditions and the wet and cloudy climate even in the summer season. Additionally, high temperatures occurring in summer months in Cyprus raise the level of difficulty for the drone flyability due to the decrease of the available time where the drone could operate and the area that can be covered.

In general, weather is important and poorly resolved to constrain that affect drone operation. According to Gao et. al. [1] air temperature, wind, speed, precipitation and other atmospheric phenomena play a pivotal role in drone endurance, control, aerodynamics, airframe integrity, line-of-sight visibility, airspace monitoring, and sensors for navigation and collision avoidance. There are situations, where drones are unable to fly but still, the decision of when, where, and how a drone will operate is predominately depend on the decision of the drone operator and the level of experience. Finally, the third point of action had to be repeatedly performed in every campaign as it was necessary to identify the precise position of the GCP marker in the drone images.

3.2 Prerequisite objectives

3.2.1 Aviation Regulations for Drones

Since 1/1/2021, the European Commission with the help of EASA (European Aviation Safety Agency) has drawn up new regulations for drone operations that have a horizontal application to every member state in the European Union. The principal goal of EASA is to promote the highest common standards of safety and environmental protection in civil aviation, and therefore the following objectives should be taken into account.

- The development of common safety and environmental rules at the European level
- The monitor and implementation of these standards through inspections in the Member States
- Providing the necessary technical expertise and training
- Closely collaborating with the national authorities that continue to carry out many operational tasks, such as certification of individual aircraft or licensing of pilots.

To ensure the free circulation of Unmanned Aircraft Systems/Vehicles (UAS/UAV) otherwise known as Drones and a level playing field within the European Union, EASA developed the following four regulations, which will replace the existing national rules in EU member states:

1. COMMISSION DELEGATED REGULATION (EU) 2019/945[3]
2. COMMISSION DELEGATED REGULATION (EU) 2020/1058 (amending 2019/945)[4]
3. COMMISSION IMPLEMENTING REGULATION (EU) 2019/947[5]
4. COMMISSION IMPLEMENTING REGULATION (EU) 2020/639 (amending 2019/947)[6]

According to such regulations, operators are able to operate their drones seamlessly when travelling across the EU or when developing a business involving drones around Europe. Common rules have a will to foster investments and innovation in this promising sector.

ICCS is responsible for the implementation of the drone flights in DIONE project, and is in line with the aforementioned regulations, having among others, certified pilots, operator registration number in order to use the drone, and many others. It should be noted that each flight campaign that is carried out in DIONE a) is fully compliant with the regulations of the two countries where the flights were conducted, and EASA aviation regulations, b) takes all the necessary precautions and safety measures for the crew, the supporting staff, c) respects General Data Protection Regulation (GDPR) rules, and d) operates with the proper drone according to the relevant category/subcategories of drone operations.

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019R0945
[4] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32020R1058
[5] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019R0947
[6] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32020R0639

3.2.2 Definition of the Regions of Interest

This section presents details regarding the definition of ROIs that were chosen to be monitored by drones. In both pilot areas of Lithuania and Cyprus, the selection of the regions and the area coverage was based on two main groups of criteria with the first to indicate the factors that are related to the local area and the second to the functionalities of the drone platform and its hardware components. In particular, the first group of criteria include parameters such as a) easy access to the region that enables the operator to perform the flights, b) regions at low altitudes and with low inclinations assisting as well to the drone operation and the efficient image collections, c) the diversity of the crop types and b) the presence of land objects with limited spatial extent, such as EFAs. Subsequently, analysing the first parameter of the second group, which is the maximum area of coverage, proper calculations were conducted before the conduction of the flights to estimate the approximate area that can be covered by a single drone flight, using one battery and at a certain height. This way, subsequent calculations can be made to find the total area coverage through one drone flight campaign that last four days and with the number of batteries that were used to be five. Secondly, the flight height of the drone was a parameter that remained stable due to the technical specifications of the drone and the national decree of the Unmanned Aerial Vehicles (UAV) that foresees the maximum flight height to be around 50m and the distance of the drone operator from the drone to be at 500m[7]. These regulations have to be addressed by the operators that belong to the "Open category".

Finally, the last criteria that should be taken into account refer to the coverage of these areas by other EO data at very high resolution, such as the satellite data provided by the ESA DWH and the archive VHR images offered by the PAs. Considering the latest, these data sources are offered every year to the PAs with a will to improve the monitoring process according to the rules of the Common Agricultural Policy (CAP). Thus, overlapping with such areas should be avoided. The following paragraphs illustrate in detail the definition of the aforementioned parameters for the establishment of the selected areas, whereas Table 5 presents a synopsis of them.

Table 4: Groups of parameters that determined the spatial extent and the location of the region of interest that will be covered in the drone flight campaigns.

Parameters related to the local area	Parameters related to the drone platform	Additional parameters related to the data
Altitude	Total covered area	Areas shouldn't be covered by available VHR data
Local Inclinations	Drone flight height	
Crop types	Single flight duration	Areas shouldn't be covered by available VHR data
Ecological Focus Areas		

3.2.2.1 Areas in Cyprus

In the case of Cyprus, the two selected areas are depicted in Figure 7. A small change of the initial definition areas of interest and especially in the second area was made, with the Paramali[8] area to be

[7] https://www.easa.europa.eu/domains/civil-drones

[8] https://en.wikipedia.org/wiki/Paramali

changed to the Choirokoitia[9] region. This modification was decided due to local legislation measurements that forbid us to perform any monitoring operations in the surrounding area. The final decision was made after a common agreement among the partners, who evaluated the main characteristics of the area, ensuring that follows the necessary requirements that were described in Section 3.2.1. Proper estimations were conducted in order to find the maximum spatial extent that could be covered by a single drone flight, using one battery. This way, subsequent calculations were made to find the total area coverage through one drone flight campaign that last four days and with the number of batteries that were used to be five. Considering the above, the total area that can be covered by each single drone flight is 240m*240m with the approximate flight at 50m. The duration per single flight is assumed to be 17-20 minutes. The following table illustrates the parameters that were defined for the calculation of the total area that could be covered in Cyprus through a single campaign.

Table 5: Characteristics of the areas that were covered in the content of the drone flight campaigns in Cyprus

Height = 50m	Total area coverage (m^2)	Total area coverage (hectares)	Approximate duration of the flight (min)
Single drone flight	57,600	4	~17-20
Daily	288000	22	105 (1h and 45')
Flight campaign (4 days)	880000	88	420
Spatial resolution = 2.2cm			

The activity was conducted through the PIX4DCapture software and the Mission Planning module that enables the user to define the mission parameters and generate a grid mission that allows to see the approximate time of each flight. An example of the planning missions as they are generated through the mission PIX4DCapture environment is depicted in Figure 6. The mission plans and the generation of the mission sub-blocks will be shown in chapters 4.1 and 0 for Cyprus and Lithuanian pilot campaigns.

Figure 6: Example of the definition of two missions in the PIX4DCapture.

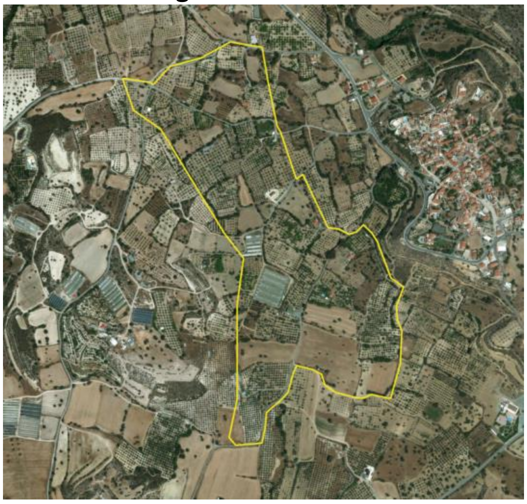
The areas that were finally determined to be monitored for the regions in Cyprus are depicted in Figure 7. Into a similar process, updates in the initial flight plans were performed in Lithuania pilot areas considering flight characteristics. Further details will be given in the chapter below.

[9] https://en.wikipedia.org/wiki/Khirokitia

1st region of interest: Akaki

2nd region of interest: Paramali

1st region of interest: Akaki



2nd region of interest: Choirokoitia

Figure 7: Updates and finalisations of selected regions for performing the drone flight campaigns in Cyprus.

Concerning the crop types, the areas are characterised by different categories including i) **annual crops** such as barleycorn, spring wheat, potatoes, ii) **permanent crops** like the watermelons and vetches, and fallow land (black and green fallow land is prohibited to be harvested within a crop year[10]), iii) **fruit trees and shrubs** land cover types as mostly olive, citrus trees and orchards. Both of the regions have also areas of high environmental value (i.e. EFAs) containing agri-environmental schemes with isolated trees. The RGB images received during the drone flights and the constructed orthomosaics will assist with the need for continuous monitoring, even when it comes to land objects with small-extent. This is particularly important for Cyprus case, where small and elongated parcels (<100m^2) are observed.

[10] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Fallow_land#:~:text=Fallow%20land%20is%20all%20arable,duration%20of%20a%20crop%20year.&text=Fallow%20land%20may%20be%3A,with%20no%20crops%20at%20all

Table 6: The crop type classes and predominately comprise the two selected areas.

AREA OF INTEREST: 1 Akaki **CROP TYPES** • Fallow land • Barleycorn • Wheat • Potatoes • Vetches • Watermelons	
AREA OF INTEREST: 2 Choirokoitia **CROP TYPES** • Olive trees • Citrus trees • Orchards	

3.2.2.2 Areas in Lithuania

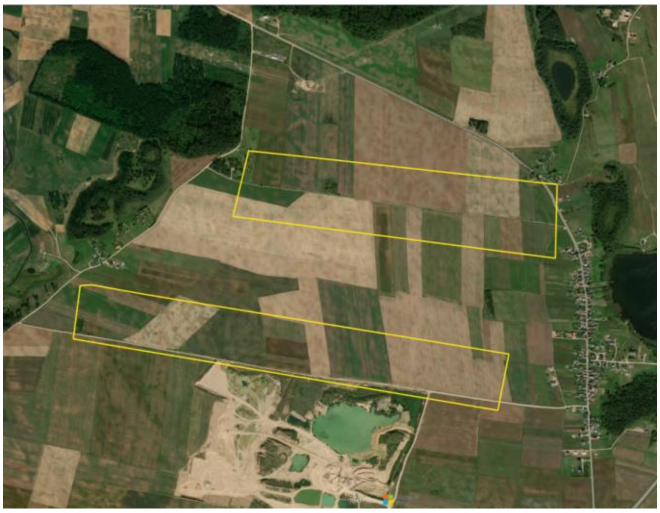
Performing a similar methodology as it was depicted beforehand for the AOIs definition in Cyprus pilot, in the Lithuanian case two regions were selected to be monitored and are depicted in Figure 8. Both of them are located near to the capital of Lithuania, which is Vilnius. Initial mission plans and modifications were made in this case as well to adapt the areas that had to be covered according to project's and users' needs and the available equipment. Supplementary equipment (i.e. batteries, battery car chargers to perform charges on the field) were acquired, aiming to extend the duration of the flights that could be achieved through each day.

Continuing, several conversations were made between the technical (ICCS) and pilot partners (NPA) before the initiation of the drone flight campaigns to Lithuania, in order to finalise the areas and the extends. As it can be seen in Figure 8, the initial rationale was to cover a wider continuous area (267 ha) and thus, at first only the AOI1 was only selected. However, it was proposed as a better solution to increase the diversity of the covered areas (and subsequently the performance of the super-resolution models) and thus, divide the initial area into two regions, which are depicted in the lower part of Figure 8. The the overall area that was covered was 248 ha, with the rest of the technical specifications, e.g. the drone flight height, the drone images' overlaps, and the number of the available batteries to be the same as it was described in the case of Cyprus.

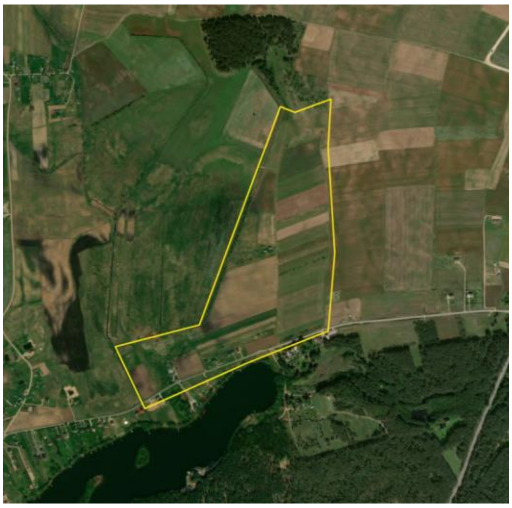
Table 7: Characteristics of the areas that were covered in the content of the drone flight campaigns in Lithuania.

Height = 50m	Total area coverage (m^2)	Total area coverage (hectares)	Approximate duration of the flight (min)
Single drone flight	133,500	13.35	~17-20
Daily	621500	62	105 (1h and 45')
Flight campaign (4 days)	2480000	248	420
Spatial resolution = 2.2cm			

1st region of interest: AOI 1 (region Vilnius)



1st regions of interest: AOI 1-sub-area 1 and sub-area2 (region Vilnius)



2nd region of interest: AOI 2 (region Vilnius)

Figure 8: Updates and finalisations of selected regions for performing the drone flight campaigns in Lithuania.

Concerning the crop types, both areas are characterised by similar types of crops as they are located in neighbouring regions. According to Table 8, the dominant crop types are the annual and winter crops covering the majority of the depicted parcels. The annual crops are mainly comprised of heterogeneous agricultural areas and in specific for this case of oats, buckwheat and potatoes. Winter crops characterised the parcels with winter triticale, wheat, rye, and barley. Subsequent crop types also occur, mainly belonging to the grassland and the fallow land, land cover types, with the first to include types such as the perennial pastures and meadows and the second black and green fallow lands. The latter along with the areas that are depicted in Table 9 are categorised in the EFAs regions. According to the greening rules of post CAP and the Recital 44 of Regulation No 1307/2013[11], EFAs have to hold at 5% of the arable land when it exceeds the 15ha. Monitoring these areas and evaluating their existence in the beneficiary parcels is of paramount importance. However, due to their small coverage within the parcels, their inspection so far was a process that was conducted by inspectors' on-the-field visits. This way, the acquisition of images that will be able to cover these small groups of isolated trees or ditches 1m wide could definitely assist the whole process and the transition to a new

[11] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:347:0608:0670:en:PDF

era where the majority of the inspections could be conducted from distance, reducing the costs, level of difficulty and the time of performing such operations.

Table 8: The crop type classes and predominately comprise the two selected areas.

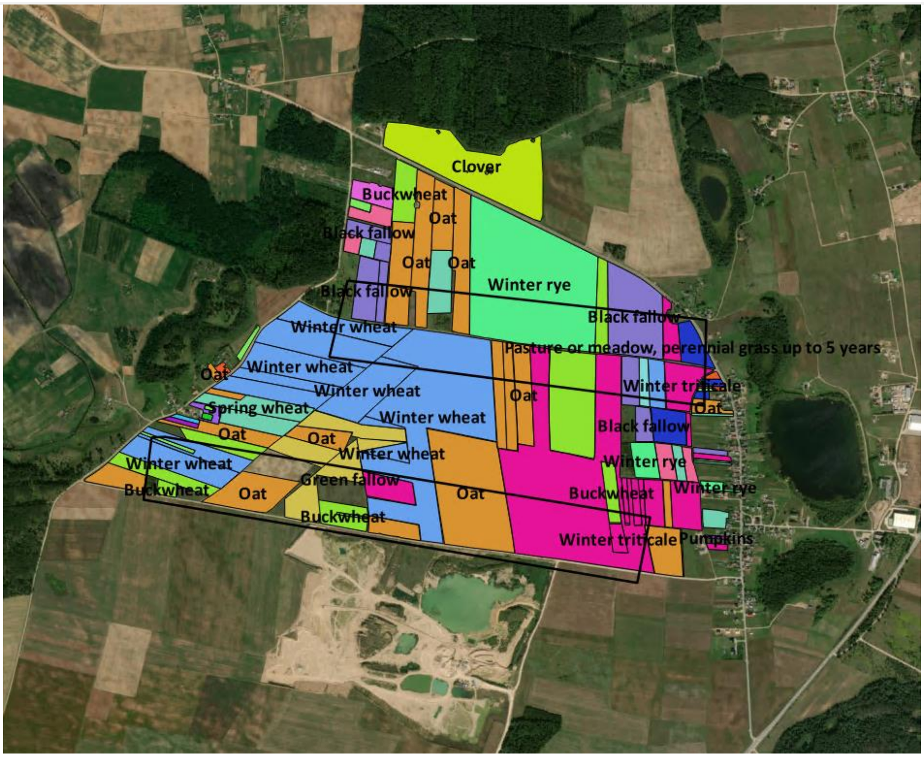
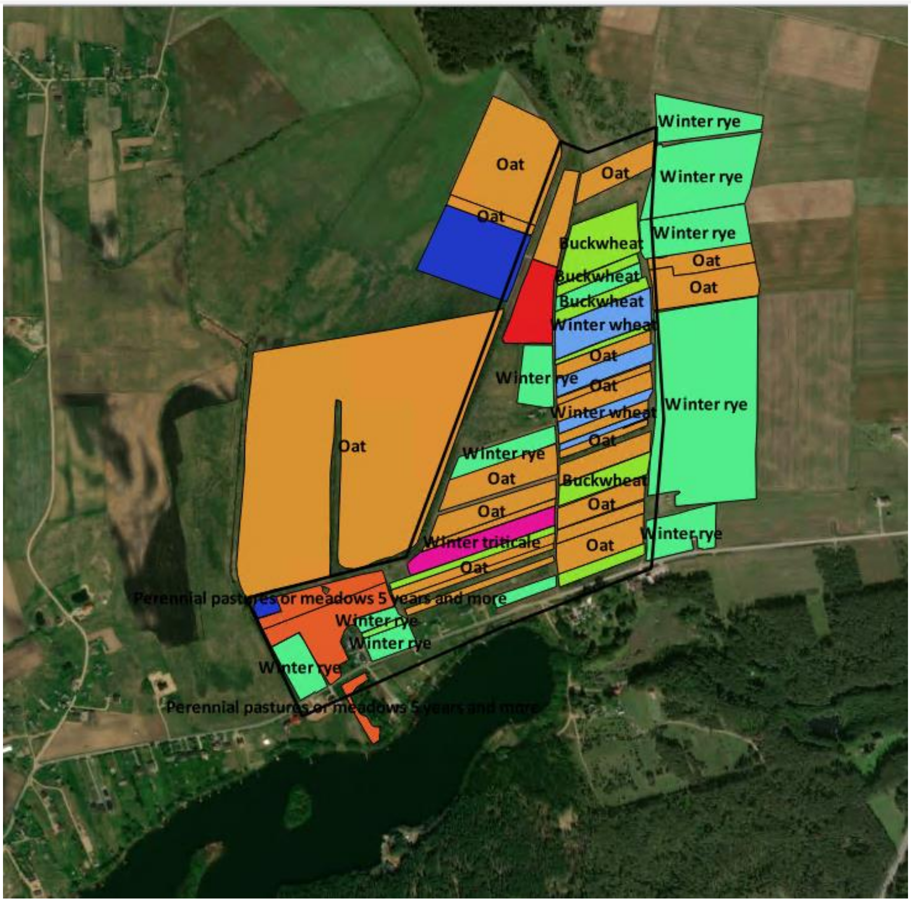
AREA OF INTEREST: 1 Vilnius Sub-areas 1 & 2 **CROP TYPES** • Oat • Green fallow • Black fallow • Winter triticale • Winter wheat • Buckwheat • Potatoes • Pasture or meadow, perennial grass	
AREA OF INTEREST: 2 Vilnius **CROP TYPES** • Oat • Buckwheat • Perennial pastures or meadows • Pasture or meadow, perennial grass • Winter triticale • Winter wheat • Winter rye • Winter barley	

Table 9: Example of Ecological Focus Areas (EFAs) in the selected regions.

Vilnius	
EFAs TYPES • Ditch, a channel from 1 m wide, the configuration of which has not changed for 3 years and more • A group of trees, a forest whose area and configuration have not changed for 3 years or more	

3.2.3 Definition of the repetitions

Another important factor concerning the process of data gathering was the definition of the period where the drone flights had to be taken place in both pilot areas. This decision was determined based on the agricultural activities and the critical changes that occur in the field during the cultivation season, which are essential to be monitored by the inspectors. For example, in the case of Cyprus three periods seemed essential for the collecting images with very-high spatial accuracy between October and December, when the planting activities occur, in March when mowing events occur and between April and June when harvesting is implemented. Subsequently, in Lithuania, the corresponding events are planned in May, and between July and September. With such information, inspectors will be able to monitor those events or to identify parcels even in the case of Cyprus that is characterised with parcels of small areas, and the preservation of areas with natural vegetation. This way, remote inspections and evaluation of the validity of the submitted declarations by farmers will be achieved. Taking into consideration all the above and the monitoring of the agricultural activities in the arable lands, three repetitions were implemented, with the exact dates to be depicted in the following table. As the needs for both pilots were similar the same number of repetitions were adopted.

Table 10: Specified number of repetitions and exact dates to perform the drone flights for both areas.

	1st flight	2nd flight	3rd flight
Cyprus			
Dates	29/3/2021- 1/4/2021	30/8/2021-2/9/2021	29/11/2021-03/12/2021
Lithuania			
Dates	24-27/5/2021	26-29/7/2021	13-16/9/2021

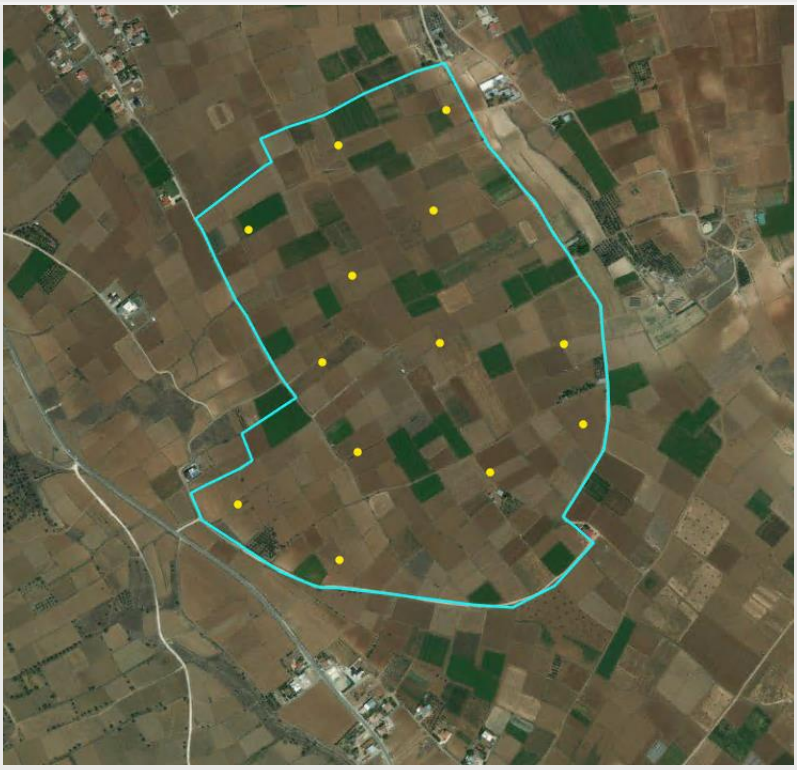
3.2.4 Enhancing the spatial accuracy of the drone orthomosaics

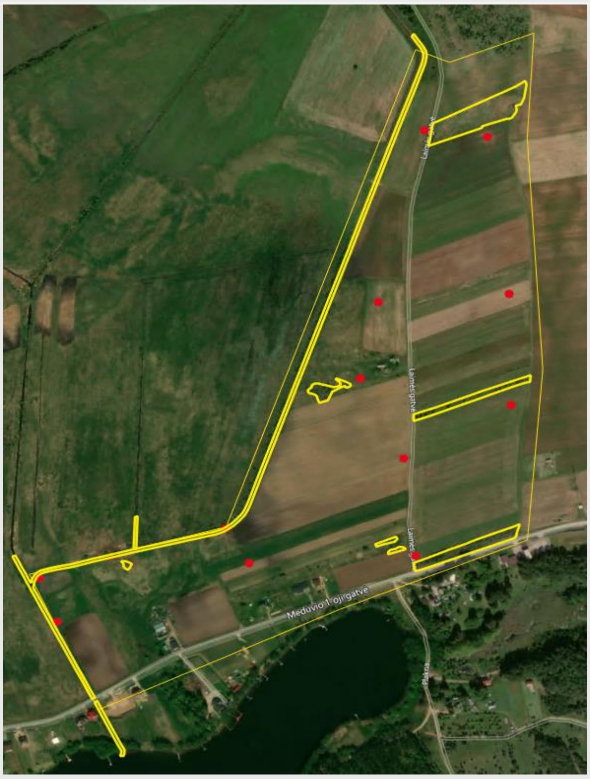
To ensure the accuracy of the generated orthomosaic products ground control points (GCPs) with an accuracy of 5-10 cm were used on each drone flight. The GPS campaign had in general two objectives, (i) to measure the GCPs to use in the aerial triangulation phase and (ii) to measure the checkpoints to assess the spatial accuracy of the resulting orthophoto. The equipment that was used to collect those points was the Topcon-GR3 GPS[12] receiver with a Real-Time Kinematic (RTK) positioning system. Subsequent markers were placed on the field before the initiation of every flight campaign, ensuring that the GCPs locations will be visible in the collected images and the georeference of the orthomosaic could succeed with greater accuracy. The GCPs' markers were placed having a notion of equal distribution among the area and in identifiable locations on the ground such as locations with high contrast in the image which could be intersections in roads, etc., and also to be easily identified and reached by the surveyors. The number of GCPs are usually based on the size of the area that is monitored and the spatial resolution of the sensor. The small-scaled projects typically require 10-20 GCPs, with the larger to require even hundreds of GCPs[13]. For our case, at least 10 GCPs were received for every AOI. The locations where the GCPs were placed are depicted in Table 11. The markers that were used for these operations have the size of 50x50x30 cm and were made with plastic material to avoid alterations due to potential moisture on the field. An example of them can be seen in this link (https://www.pix4d.com/blog/why-ground-control-points-important). The points having measurements of latitude, longitude and height were exported in the coordinate systems of WGS84 UTM34N for Lithuania and UTM36N for Cyprus make them feasible to be inserted in the Agisoft Metashape Professional software in CSV format for the implementation of the photogrammetry georeferencing [2].

[12] https://gnssgpssystems.net/topcon-gr-3-gps-glonass-rtk-base-or-rover-digital-uhf-receiver/

[13] https://trajectorymagazine.com/ground-control-points/

Table 11: Distribution of the ground control points over the regions where the drone flight campaigns were performed.

Cyprus	
	Choirokoitia region
	Akaki region
Lithuania	

	AOI1 sub-region 1
	AOI1 sub-region 2
	AOI1 2

3.3 Performing test flights with the UAV platform

3.3.1 Overview of the implementation process

To ensure smooth flight campaigns and end-end successful capture of proper data and processing an extensive test flight was conducted in Lavrion Technological Cultural Park (LTCP), Greece, (https://en.ltcp.ntua.gr/) of the National Technical University of Athens (NTUA). The selected area, having ground and vegetation (i.e., Pursuing to be closer as can be to the use cases of DIONE) that was mapped is depicted in Figure 9.

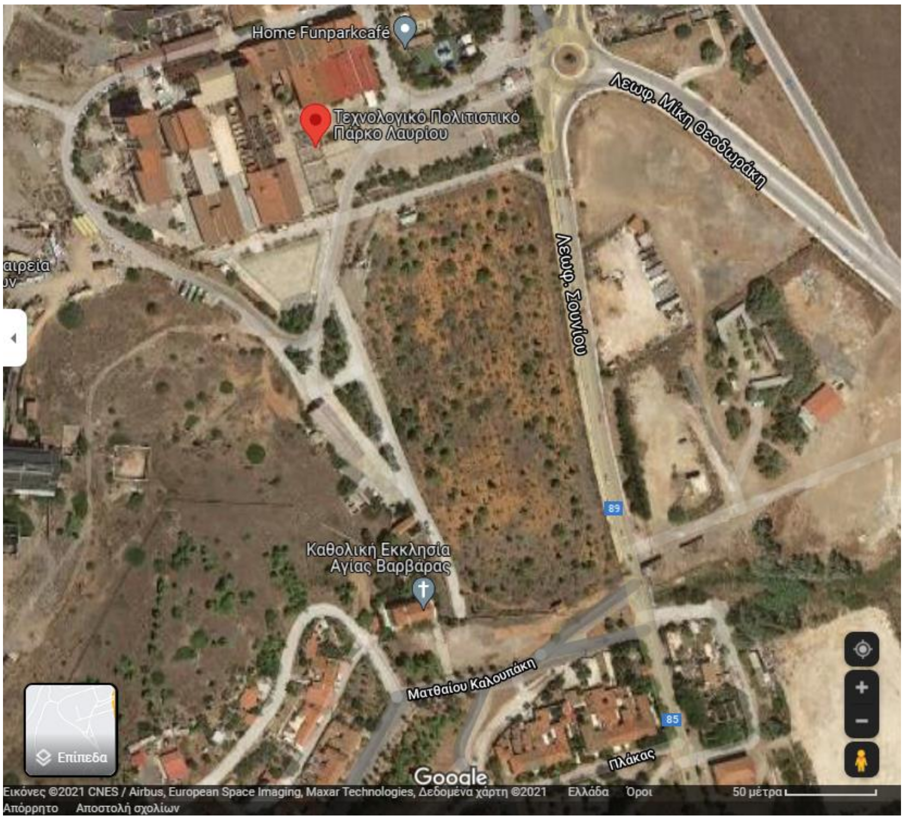


Figure 9: Area of interest (yellow rectangle) to be mapped for the test flight in LTCP, Greece (Source image: Google Maps (https://www.google.com/maps).

Some of the main preparation activities were: i) the design of safety and risk assessment plan (e.g. alternative positions for land/take off, control measures, highlight possible hazards, etc), ii) to ensure proper weather conditions (no rain, no fog, no winds, etc), iii) to pre analyse the area to be mapped (terrain, affected infrastructure, air traffic/ Notices to Airmen (NOTAMs), obstructions, other restrictions/limitations, take off/land positions, etc), iv) proper preparation of the used equipment (drone check and electronics, remote controller, batteries, etc) and, v) firmware update and fine-tuning of the used software for effective, adapted and safe flight control and flight missions, and vi) check camera settings and proper functioning.

3.3.2 Output results

As the first step, the flight plan and the corresponding missions were designed and uploaded to the flight control software, (Figure 10).

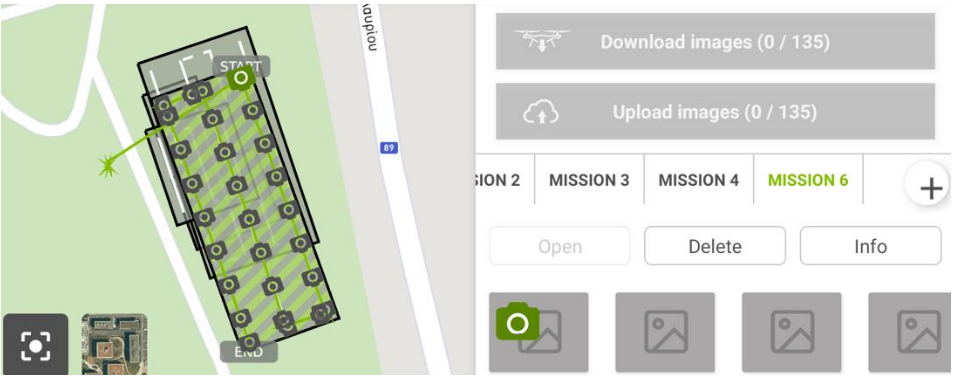


Figure 10: Uploaded flight plan and the corresponding missions to the flight control software (PIX4D capture- https://www.pix4d.com/product/pix4dcapture).

Several missions were carried out to fine-tune the main settings of the flight mission such as flying height (e.g., 35m and 50m) and image capture overlap (e.g., 70% and 80%). 160 images were collected, however, 28 of them were selected for the generation of the orthomosaic of the area of interest. The 28 images were added to Agisoft Metashape software (https://www.agisoft.com/) to be further processed and aligned. Figure 11 shows the added images while Figure 12 their corresponding overlap after their alignment process using their external orientation of camera locations (in WGS'84).

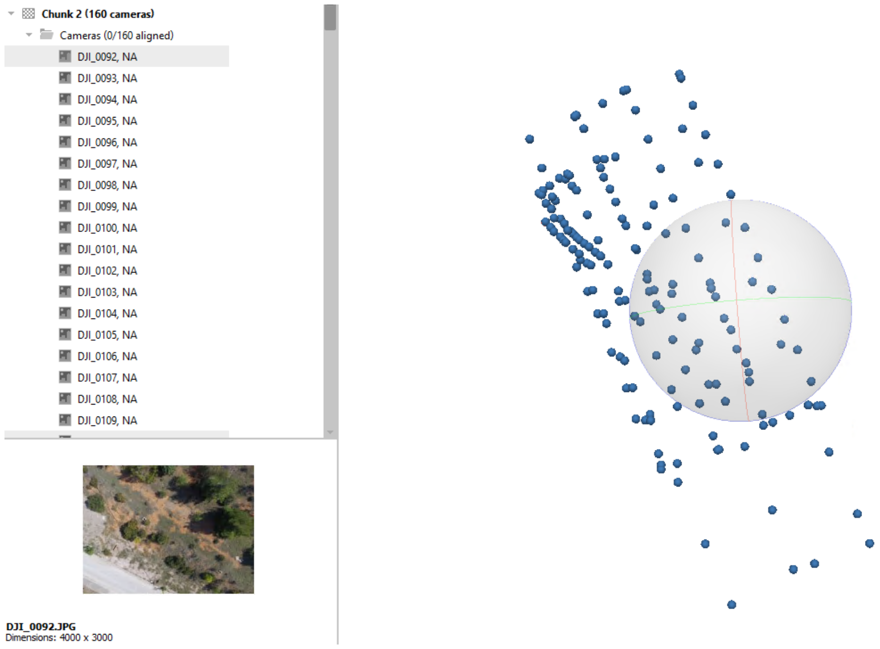


Figure 11: Added images and camera position

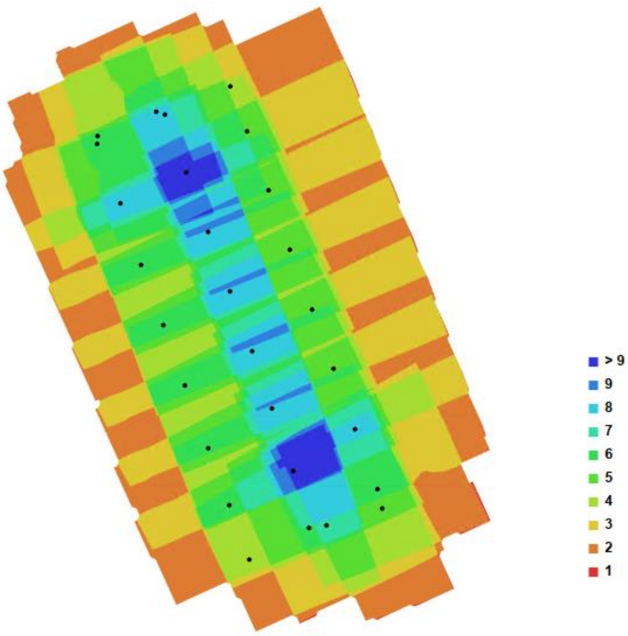


Figure 12: Image overlap using camera locations from external orientation location in WGS'84.

Then, the dense 3D point cloud of the area of interest was extracted through the automatic 3D reconstruction process and the Digital Surface Model (DSM) was generated afterwards (Figure 13). In the last step, the final orthomosaic of the area of interest was generated. Figure 14 shows the final generated orthomosaic overlaid to basemap to brief check the corresponding georeference. It is noted that no control/checkpoints were used for the generation of the orthomosaic for this test flight.

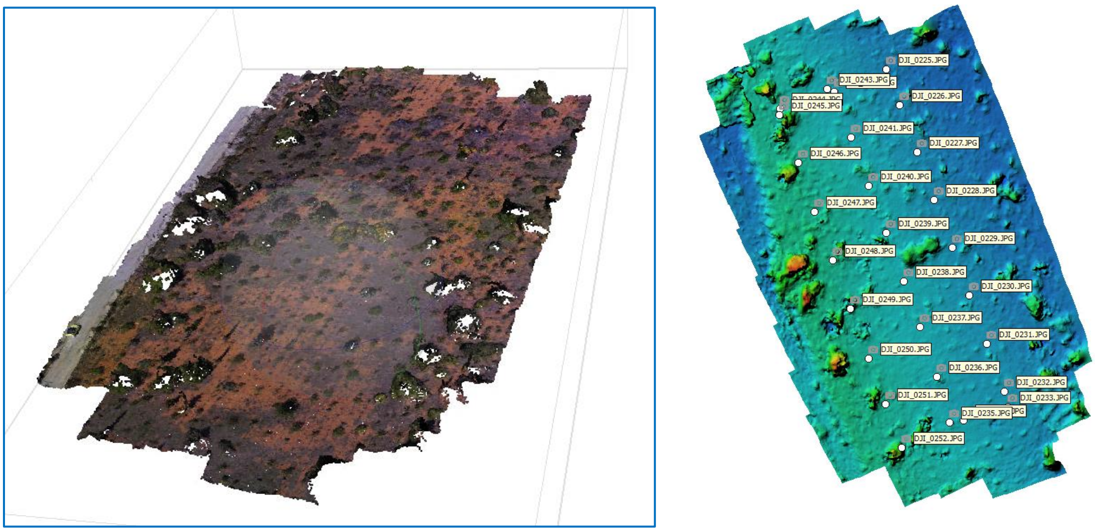


Figure 13: 3D dense point cloud (left) and DSM with camera locations overlaid (right)

Figure 14: Final orthomosaic of the area of interest overlaid to basemap

In conclusion, the results are considered satisfactory, highlighting the necessity of such test flight (to be familiar with all the system's components as well as to optimize flight parameters and software tuning) and proving that high-quality geographical products (point cloud, DSM, and orthomosaic) are generated with proper georeference.

3.4 COVID-19 pandemic local restrictions

COVID-19 outbreak affects the data collection related activities. In the context of DIONE, every arranged drone flight was performed following all the protocols were established against COVID-19, including the conduction of the specific PCR tests before the flight dates and the corresponding traveller's digital passports in order to have certified proof of being compliant with the COVID restrictions. In the case of Lithuania, as in the first two drone flights, the whole country was under lockdown restrictions, the drone operator followed all the necessary protocols, having as well the necessary documents that allowed him to move to the areas of interest where the drone flight campaigns had to take place.

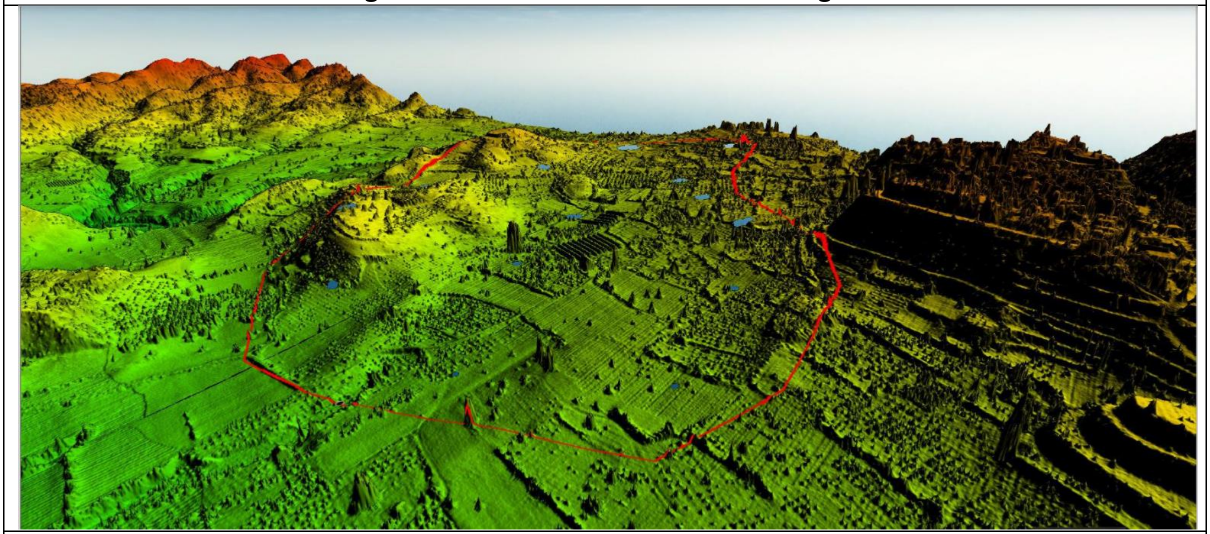
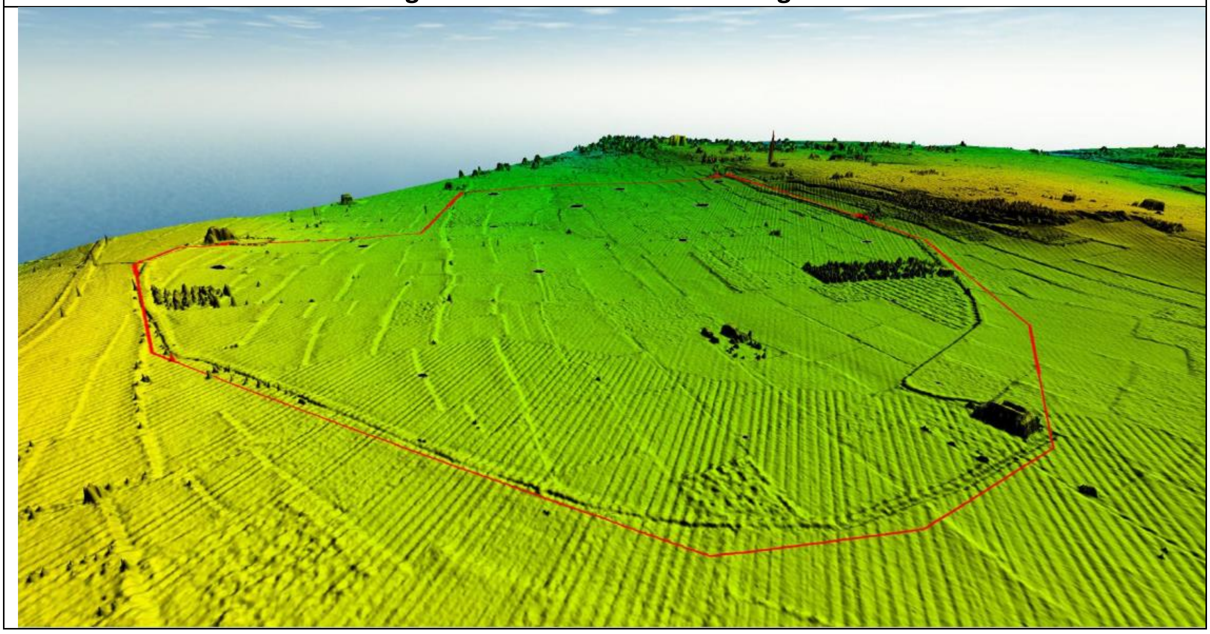
4. Drone flight campaigns

In the former chapters, we showcased all the necessary procedures that synthesise the UAV platform, which is responsible for the generation of the VHR RGB images. Both the technical components that comprise this platform, as well as the implementation of a test flight mission, are explained in detail in order to ensure that during the final demonstrations in Cyprus and Lithuania, all the necessary steps will be conducted following the well-defined concept. In the next two chapters, we depict the corresponding results of the overall 6 flight campaigns that were performed for the needs of the project.

4.1 Pilot region demonstration: Cyprus

Starting with the first pilot case in Cyprus, before the initiation of the flight missions, the digital surface models, received from the National Cadastral Agency in Cyprus, were tested to better understand the landscape of the area, and organise the subsequent mission paths, where the drone will go through. Table 12 depicts the digital surface models (DSM) that assist us to conduct this preliminary analysis of the area. In general, a drone flight survey has to be conducted in areas with a homogeneous surface, with the surface inclinations to have slight changes. Taking the aforementioned into consideration, we generated the mission plans with a notion of each sub-mission to be comprised by sub-blocks with similar terrain, while this way the greatest accuracy of 2D orthomosaics without significant distortions in the image could be achieved. Appendix (10) reveal more examples of the local surface of the areas (Table 17 and Table 18). Additional examples of the different vertical and horizontal altimetric incisions that were made alongside the DSMs to have a more detailed view of the local altimetric changes of the surface.

Table 12: Digital Surface models of the two monitoring areas in Cyprus.

Digital Surface model of Choirokoitia region

Digital Surface model of Akaki region


The extensive flight campaigns were performed following all the parameters that were described in chapters 2 (technical summary) and 3 (determined parameters and performance of drone tests flight). In particular, the corresponding preparation activities were implemented every day and before the initiation of the flight mission, with the most critical to be (i) checking for good weather conditions, (ii) the positions where the drone will be taking off and landing in the sub-mission flights, and (iii) the proper preparation of the equipment, including the battery charge before the next flight.

The flight plan for the Cyprus flight missions was designed for both regions and uploaded to the Pix4D Capture software and presented in Figure 15. The approximate number of drone images were created in every campaign is 1500 for the Akaki region and 940 for the Choirokoitia region. Minor shifts in the total number of images might occur between the flights as all the parameters (e.g. drone height, number of batteries, percentage of the images' overall) remain the same. A critical step was to calibrate the camera before undergoing model reconstruction so that the model produced has a high level of accuracy. According to Yudhi Rezaldi et. al. [3], this step is mandatory in case an image is captured by a different camera. The visual results of the 3D orthomosaic modelling process and the generation of the orthomosaic final images are shown in Figure 16 and Figure 17. The output products for the three drone flight campaigns are depicted in Table 13 and Table 14.

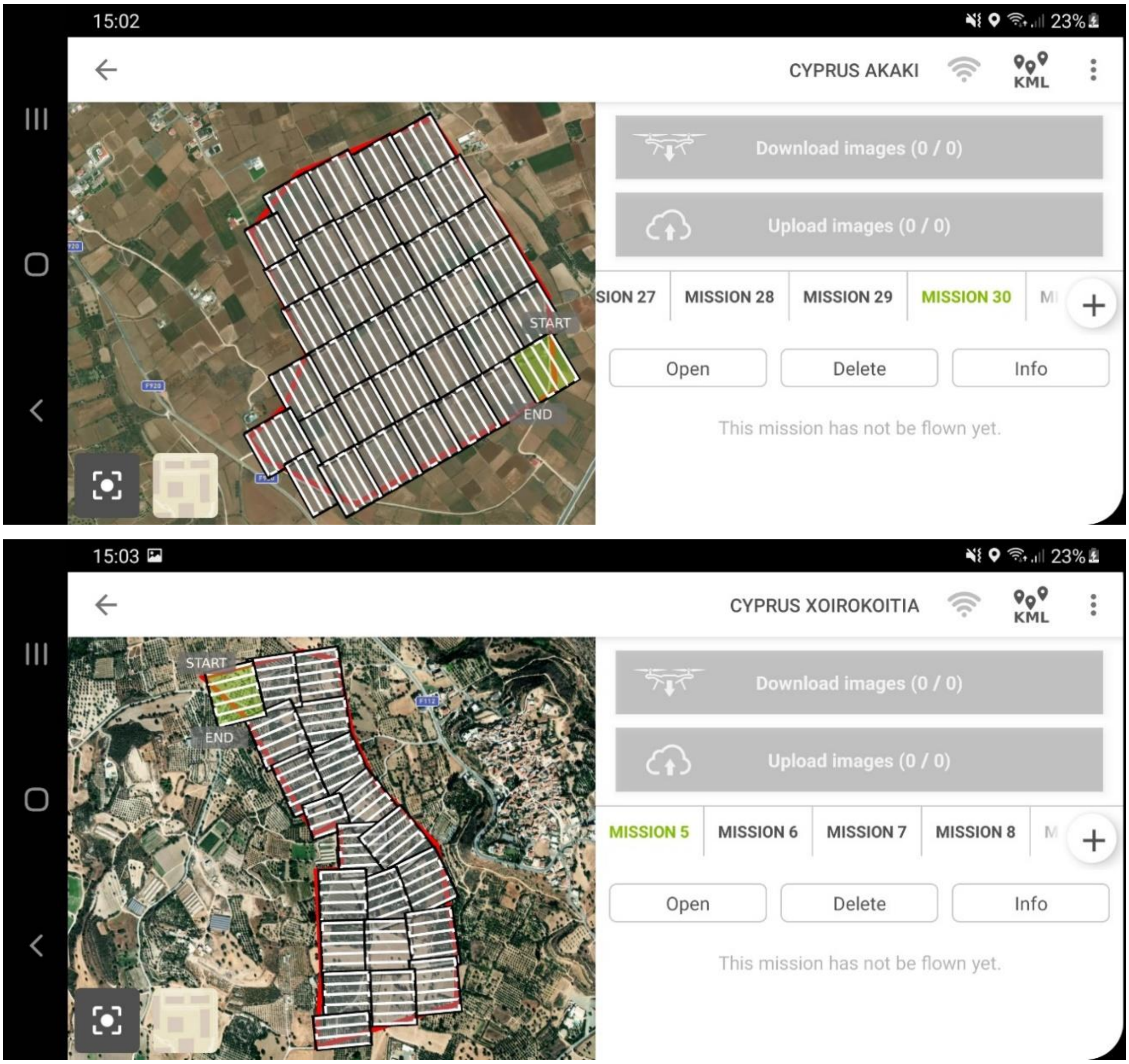


Figure 15: Flight plans in the left for the Akaki region in the right for the Choirokoitia, as they are depicted in the Pix4D Capture software.

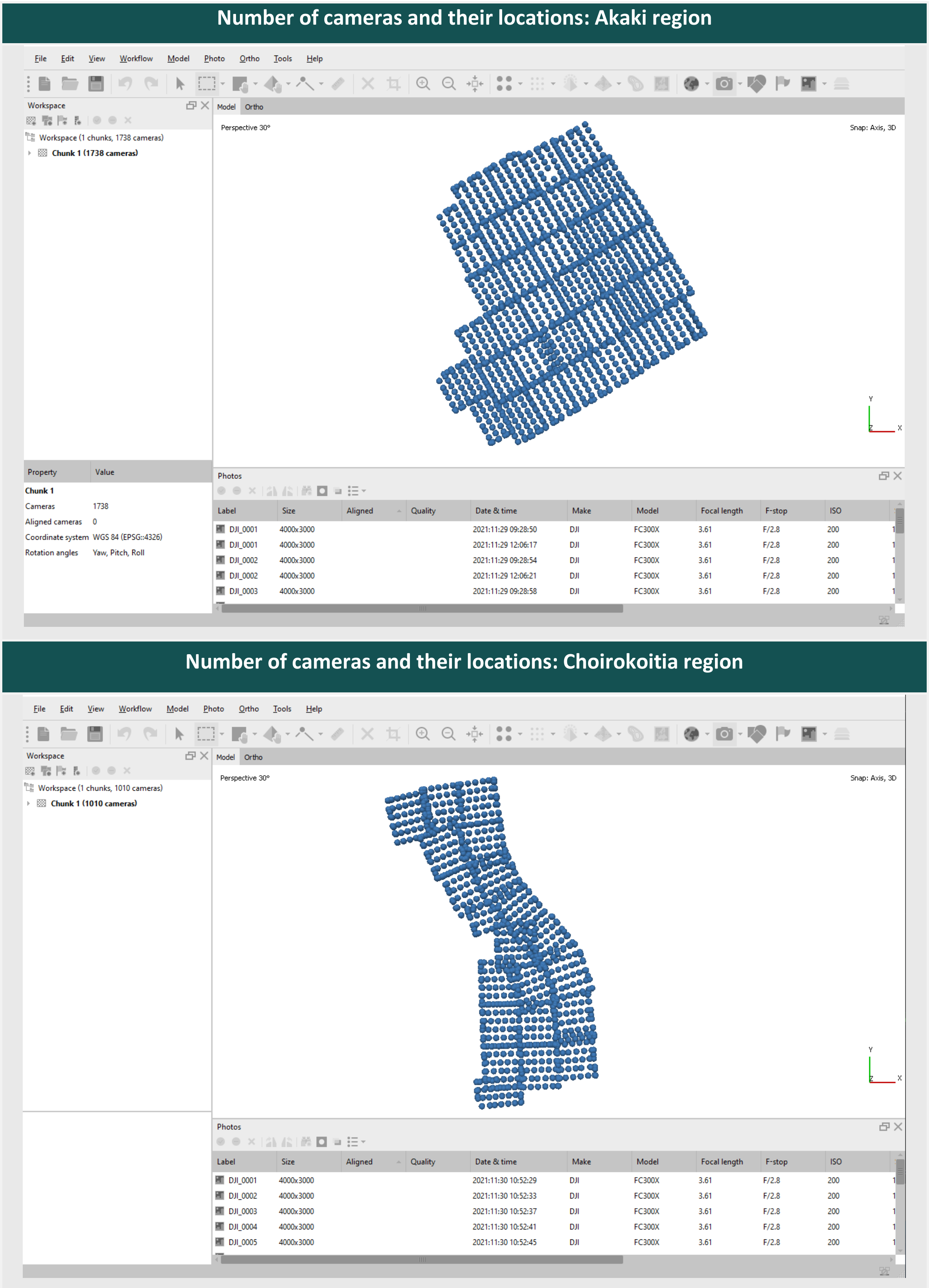
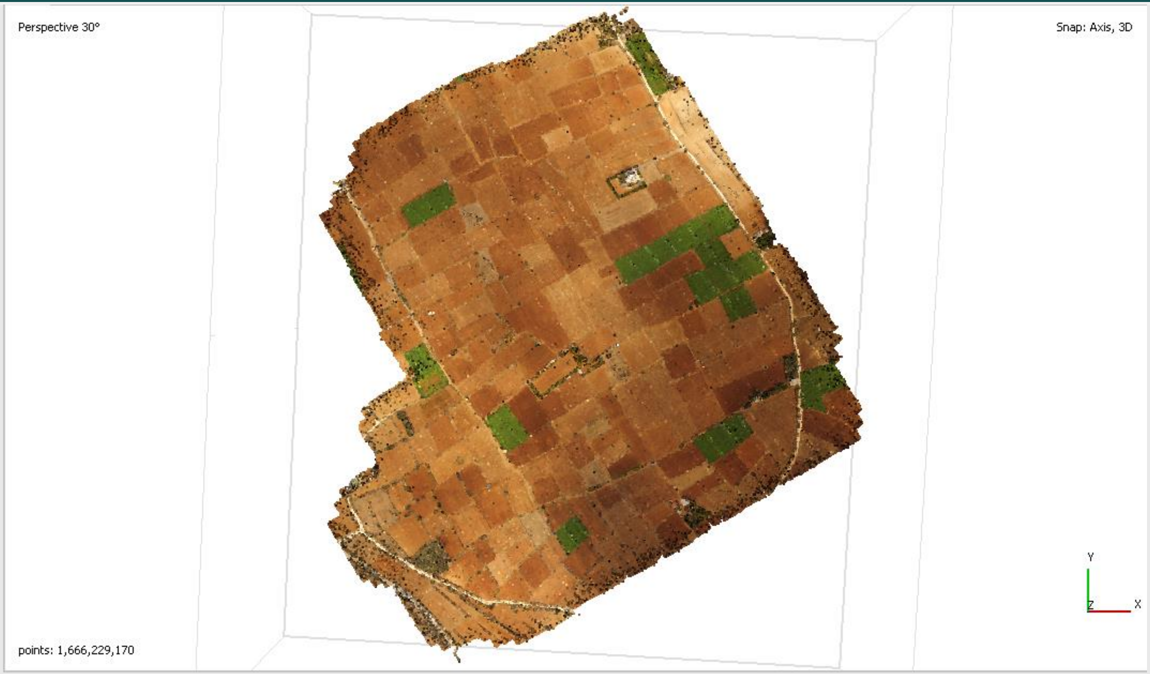
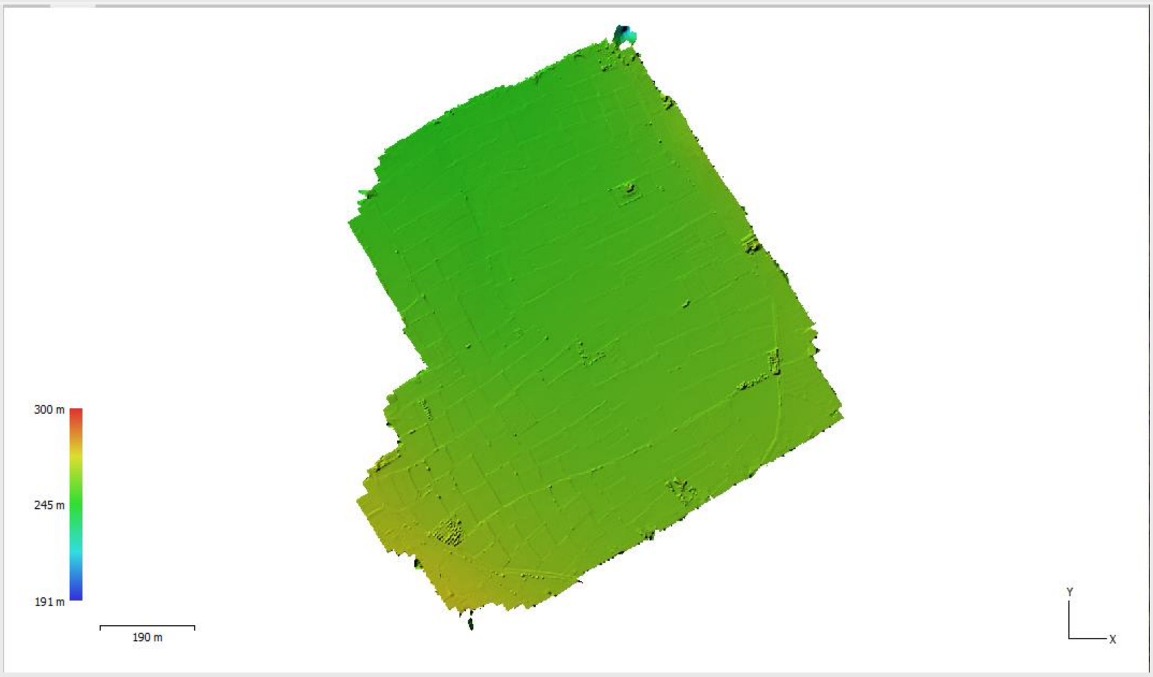


Figure 16: Number of depicted image cameras: top-image – Akaki region and bottom image – Choirokoitia

3D dense point cloud & Digital Surface Model: Akaki region





3D dense point cloud & Digital Surface Model: Choirokoitia region

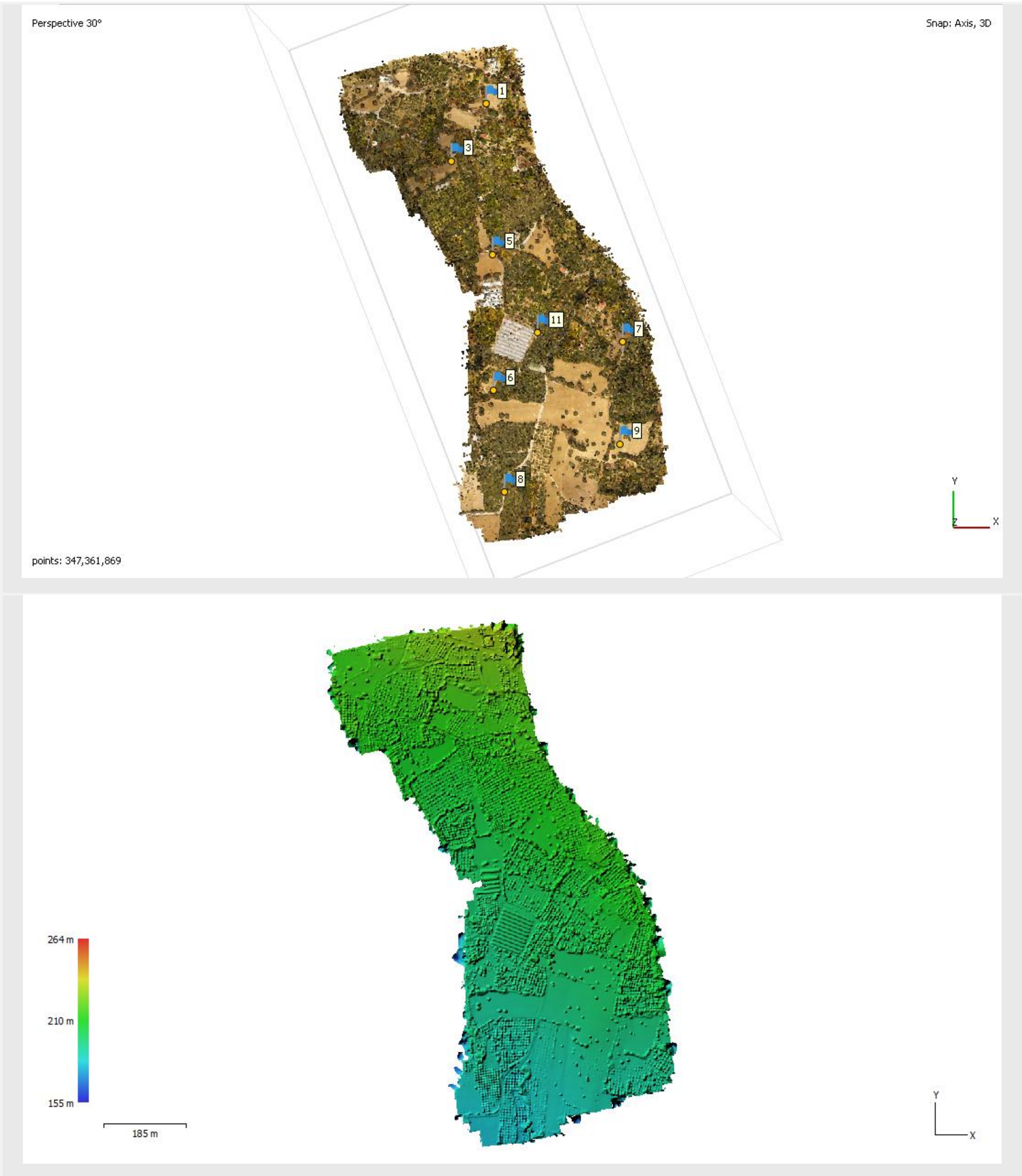


Figure 17: Generated 3D point cloud and the corresponding Digital Surface Model: top two images – Akaki region and bottom two images - Choirokoitia

Table 13: The generated image orthomosaics in the Akaki pilot region

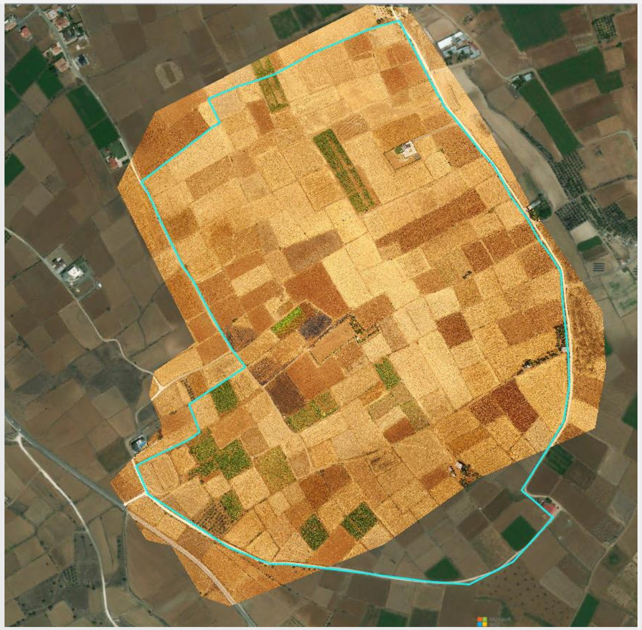
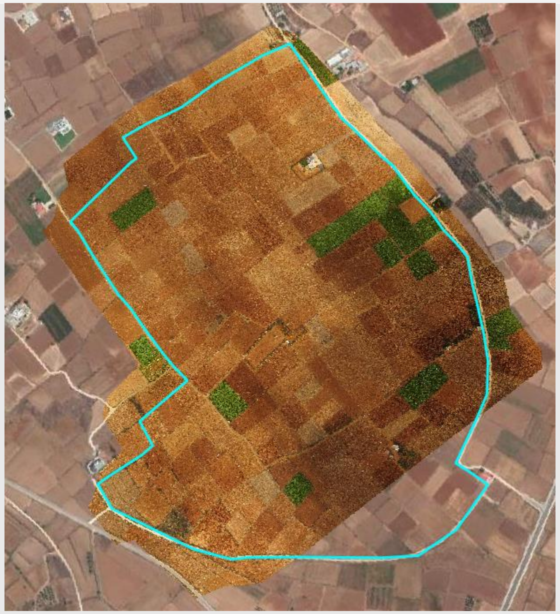
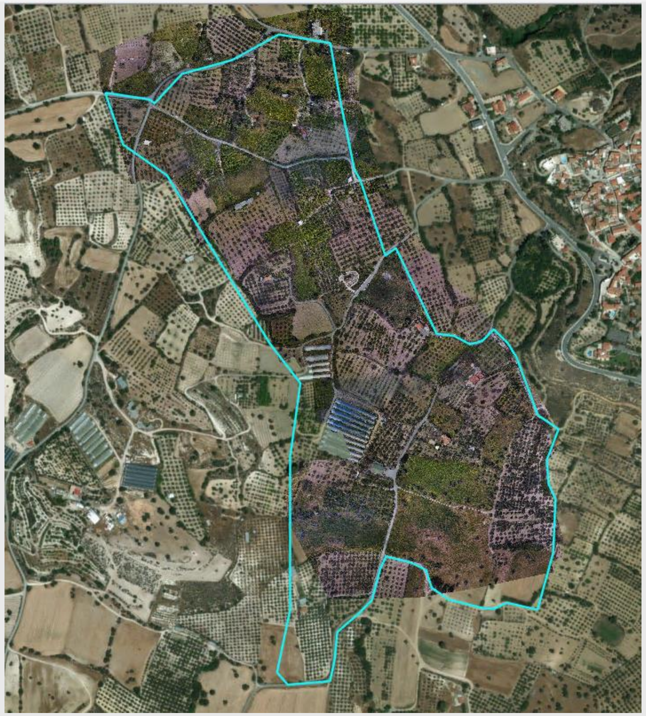
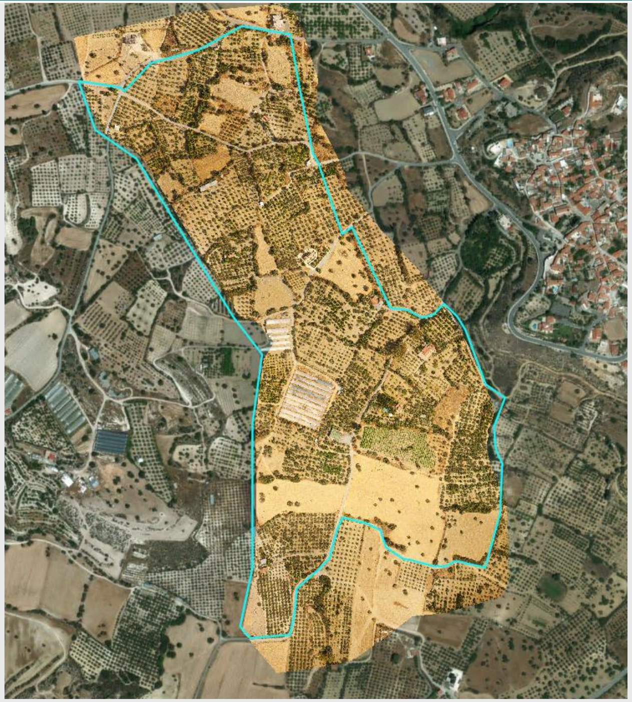
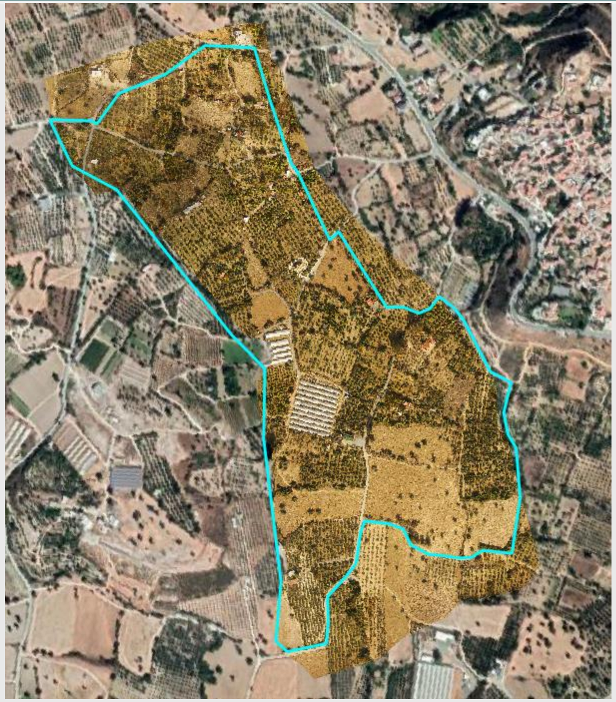
Generated VHR orthomocaics: Akaki region		
1st flight: 29/3/2021- 1/4/2021	2nd flight: 30/8/2021-2/9/2021	3rd flight: 29/11/2021-03/12/2021
		

Table 14: The generated image orthomosaics in the Choirokoitia pilot region.

Generated VHR orthomocaics: Choirokoitia region		
1st flight: 29/3/2021- 1/4/2021	2nd flight: 30/8/2021-2/9/2021	3rd flight: 29/11/2021-03/12/2021
		

4.2 Pilot region demonstration: Lithuania

Moving to the demonstration of the drone flight campaigns that were arranged in Lithuania, in this case, prior evaluation of the local landscape of the area and elevation range wasn't necessary as in general both areas of interest was characterised by negligible slopes, and therefore the performance of the flights wasn't affected by this parameters. In this case, the most critical parameter was the weather conditions, as in half of the years the areas as covered by snow (i.e. for sure until March) and by intense rainfalls and winds. Taking into consideration the above conditions, the drone flights campaigns were always finalised in terms of the specific dates that will be conducted, with the frequent verification of weather, until the last days before the campaign.

Following the same procedure that was described in the demonstration of the Cyprus case, 2.391 and 1.531 images were created in every campaign, for the AOIs 1 and 2, respectively. The simulated flight plans for both regions are depicted in Figure 18. The visual results of the 3D orthomosaic modelling process and the generation of the orthomosaic final images are shown in Figure 19 and Figure 20. The output products for the three drone flight campaigns are depicted in Table 15 and Table 16.

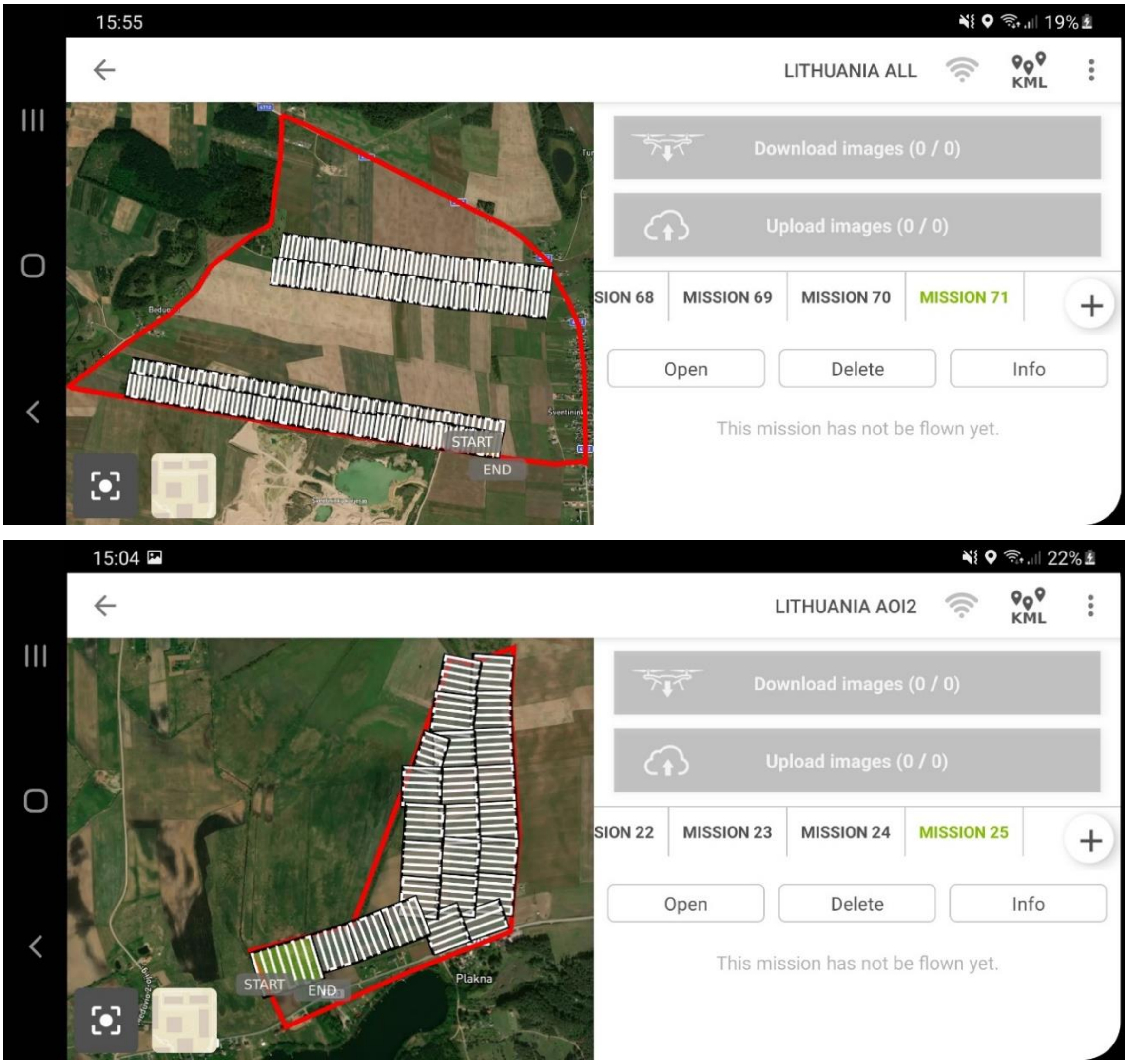
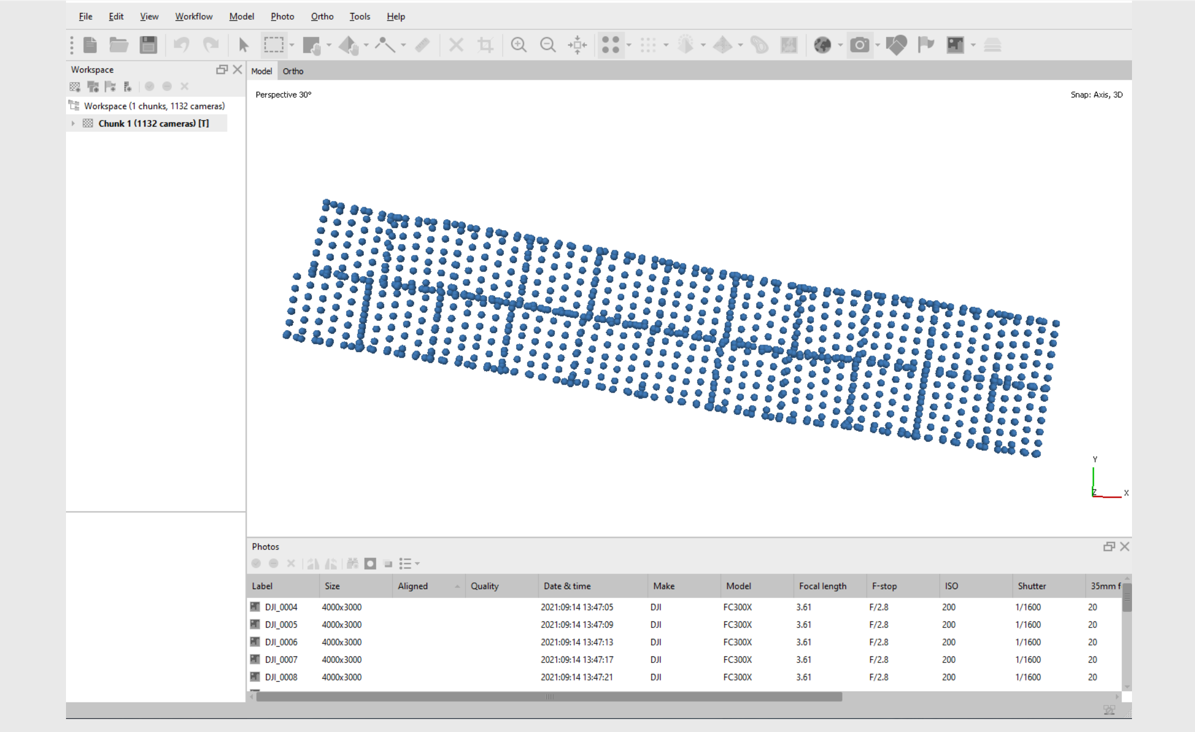
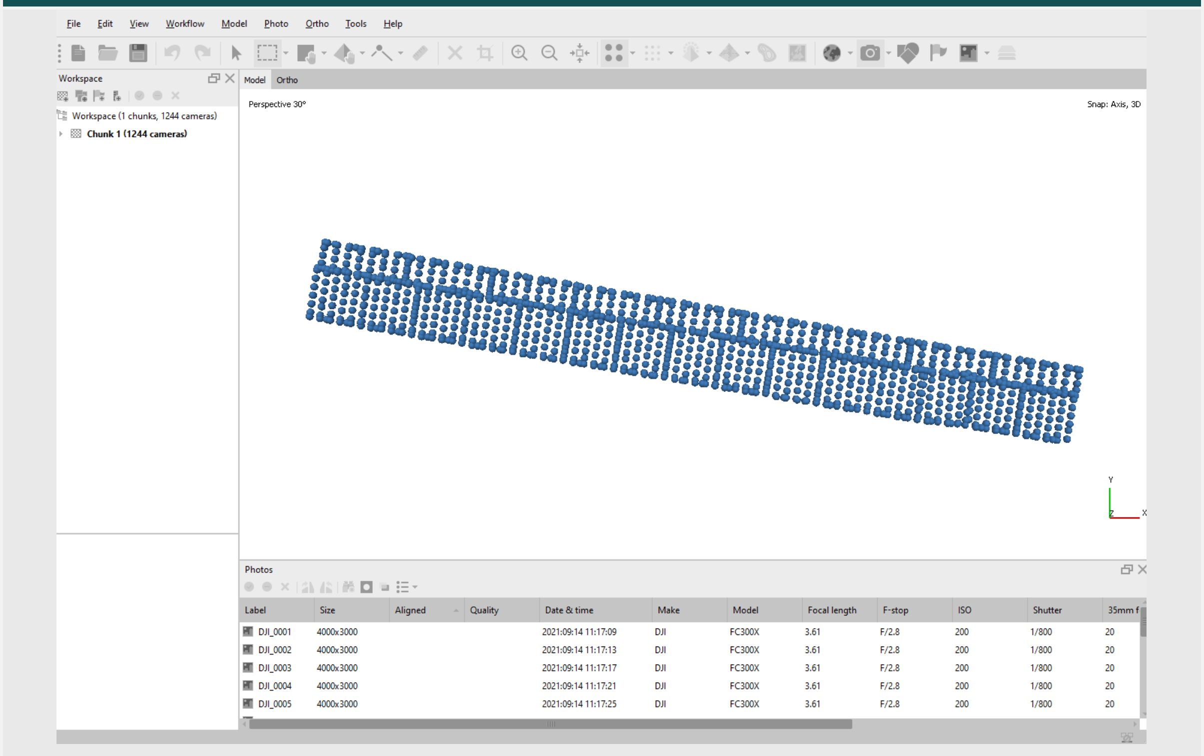


Figure 18: Flight plans in the left for the AOI1, sub-regions 1 and 2, in the right for the AOI2, as they are depicted in the Pix4D Capture software.

Number of cameras and their locations: AOI 1 sub-region 1



Number of cameras and their locations: AOI 1 sub-region 2



Number of cameras and their locations: AOI 2

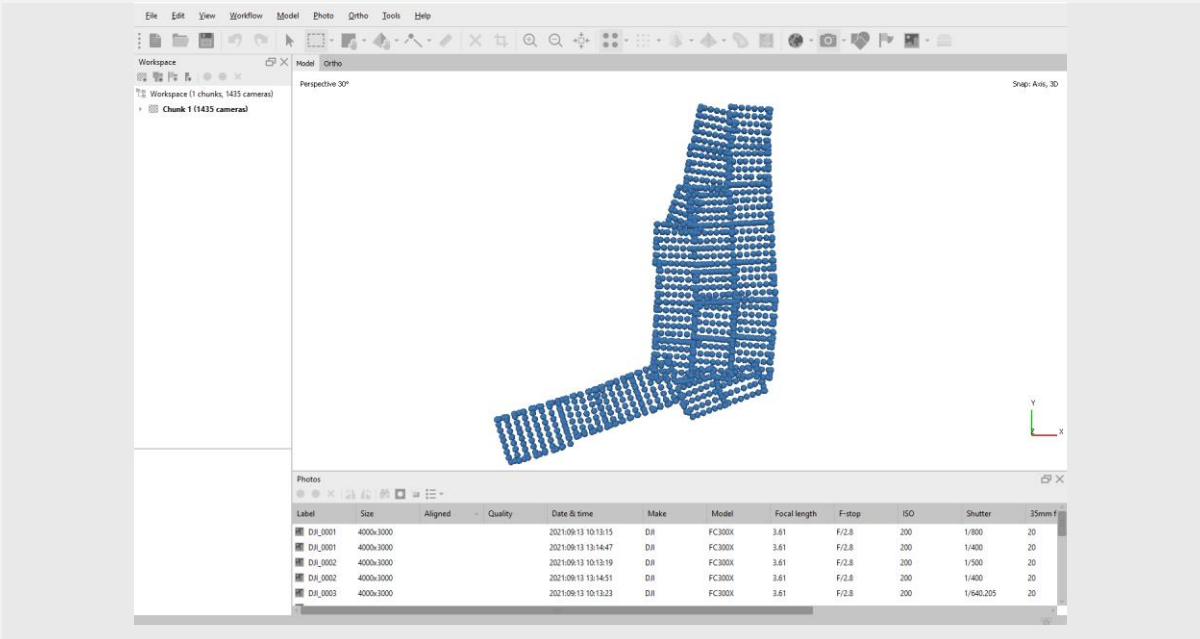
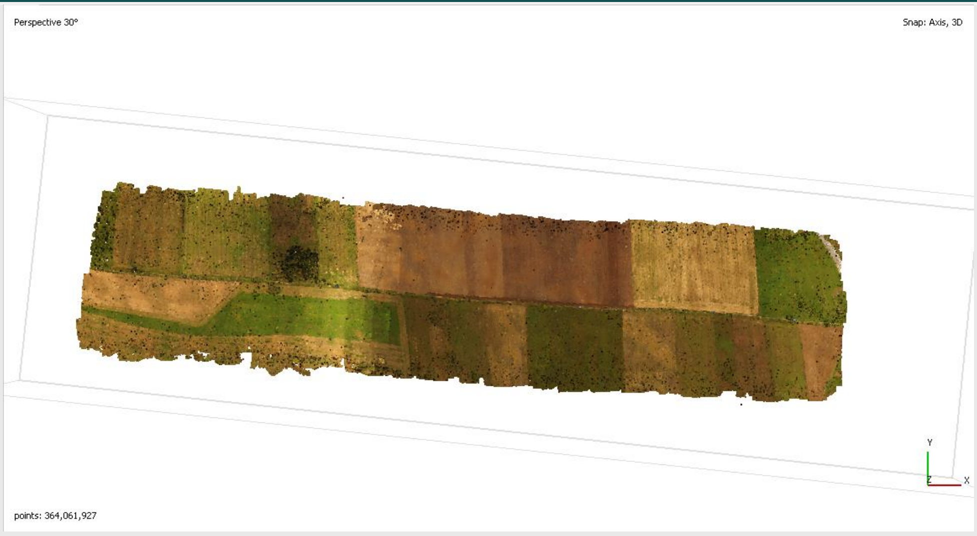
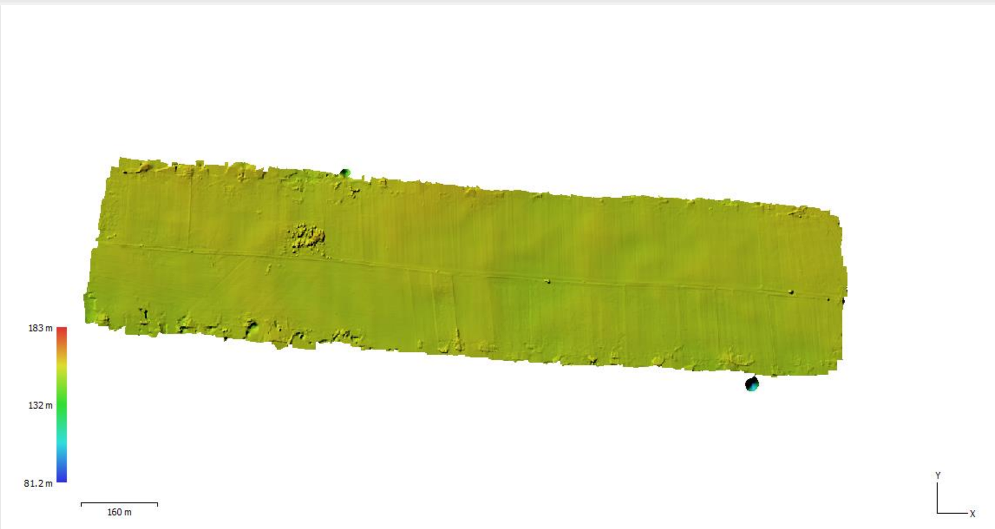
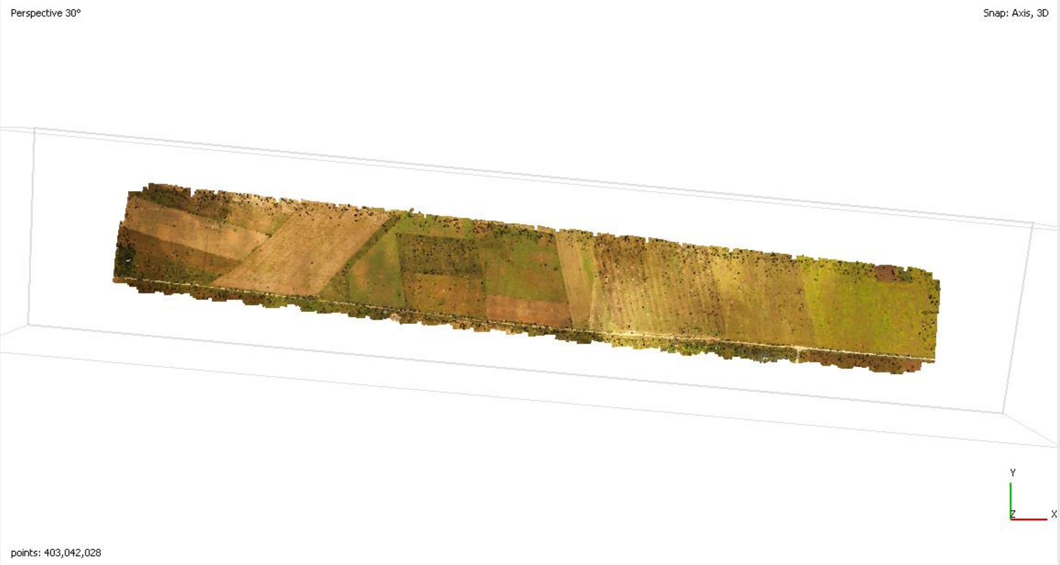
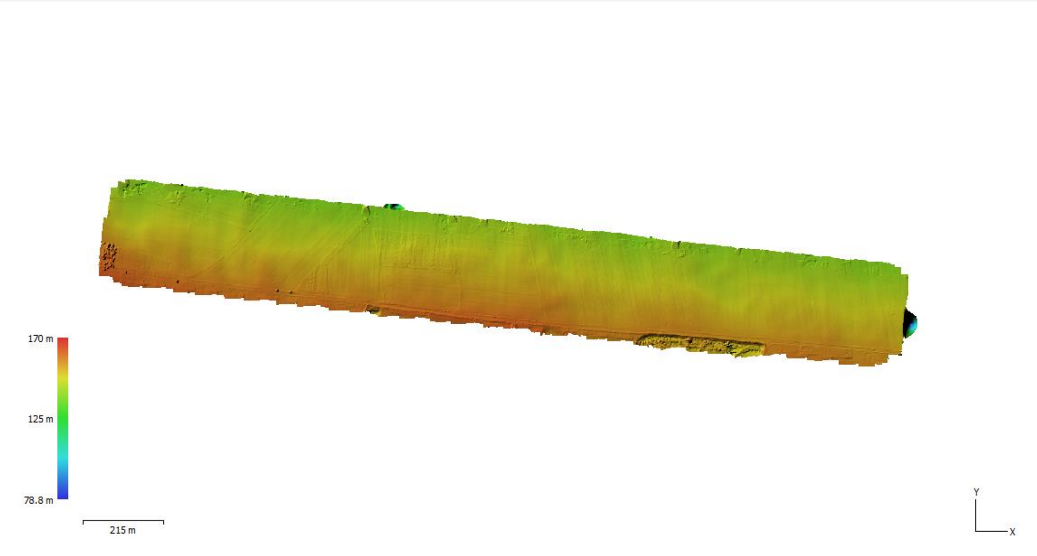


Figure 19: Number of depicted image cameras: top-images – AOI1, sub-regions 1 and 2 and bottom image - AOI2.

3D dense point cloud & Digital Surface Model: AOI 1 sub-region 1





3D dense point cloud & Digital Surface Model: AOI 1 sub-region 2


3D dense point cloud & Digital Surface Model: AOI 2

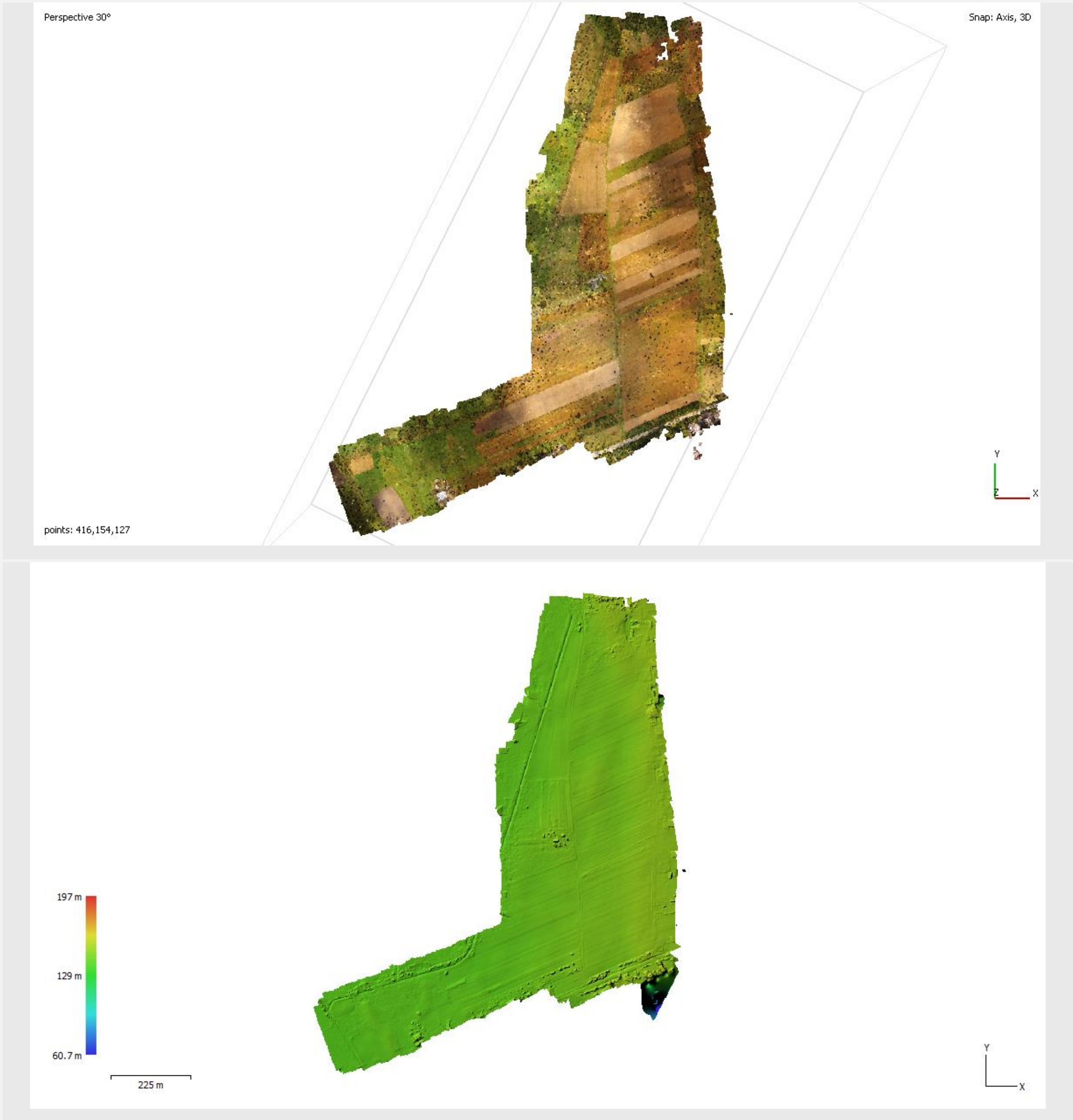
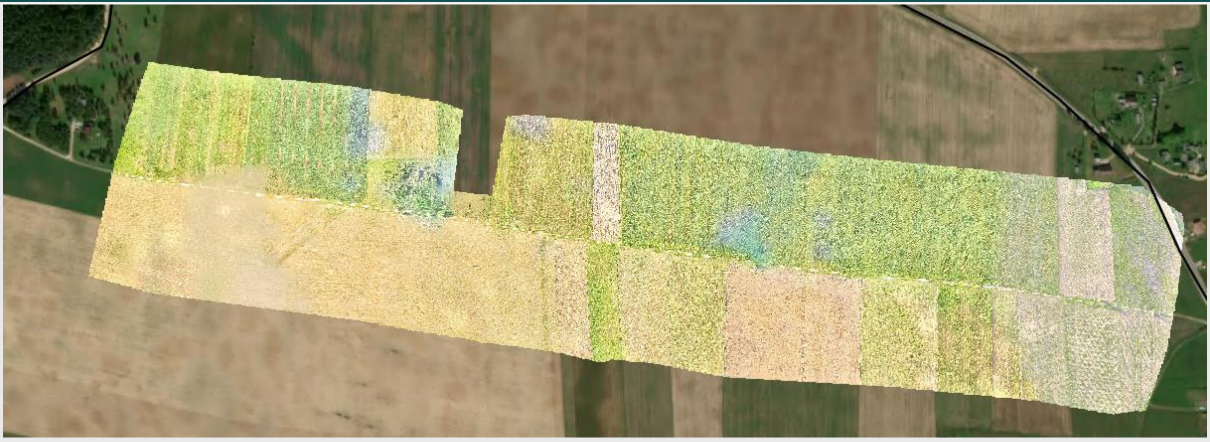
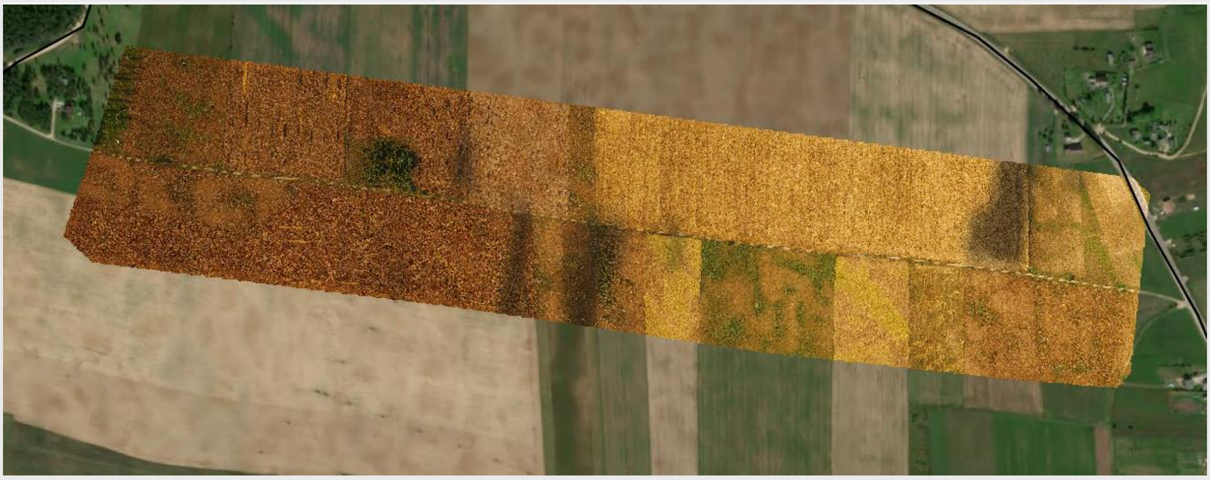
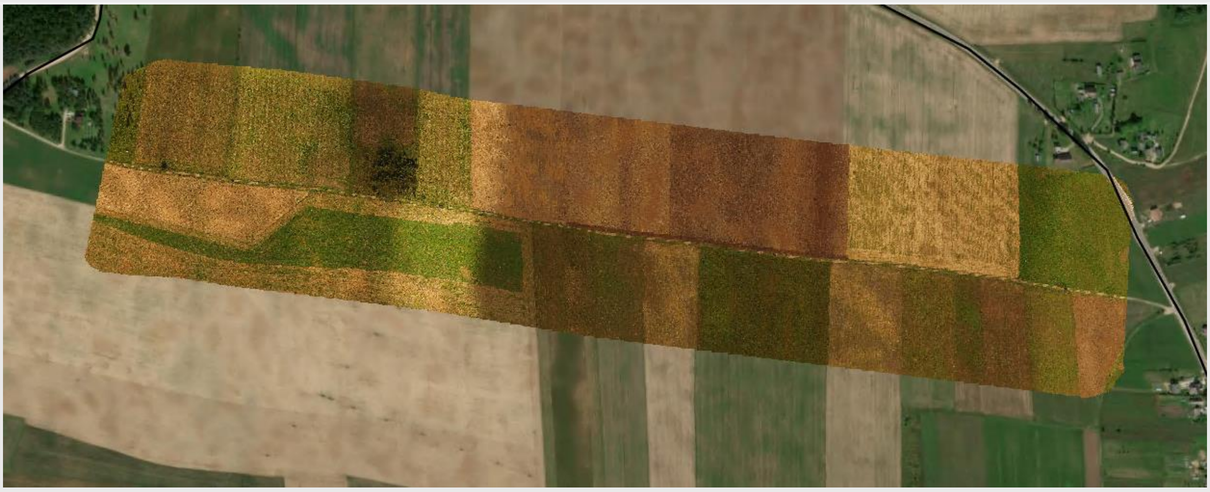


Figure 20: Generated 3D point cloud and the corresponding Digital Surface Model: top two images – AOI1, sub-region 1, Images in the middle - sub-region 2, and 2 and bottom images - AOI2.

Table 15: The generated image orthomosaics in the AOI1 and in specific the sub-regions 1 and 2.

	Generated VHR orthomocaics: AOI 1 sub-region 1
1st flight 24-27/5/2021	
2nd flight 26-29/7/2021	
3rd flight 13-16/9/2021	
	Generated VHR orthomocaics: AOI 1 sub-region 2

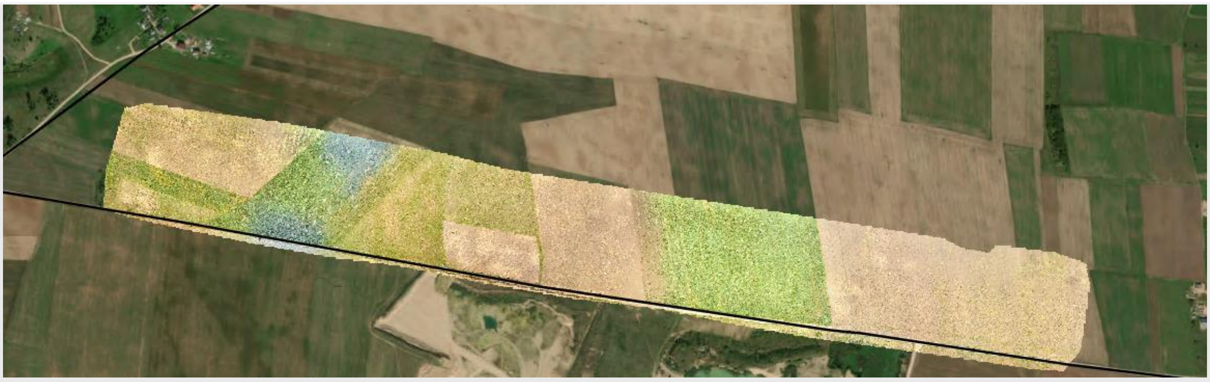
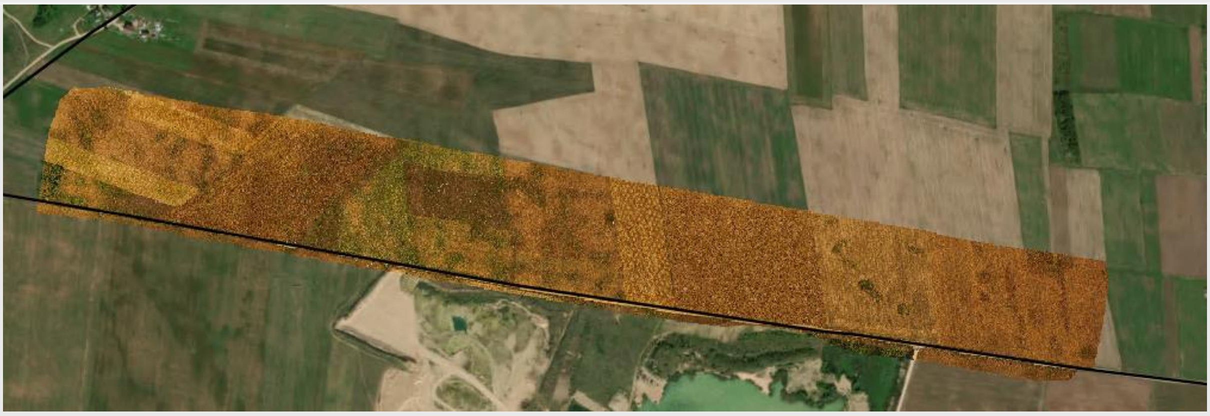
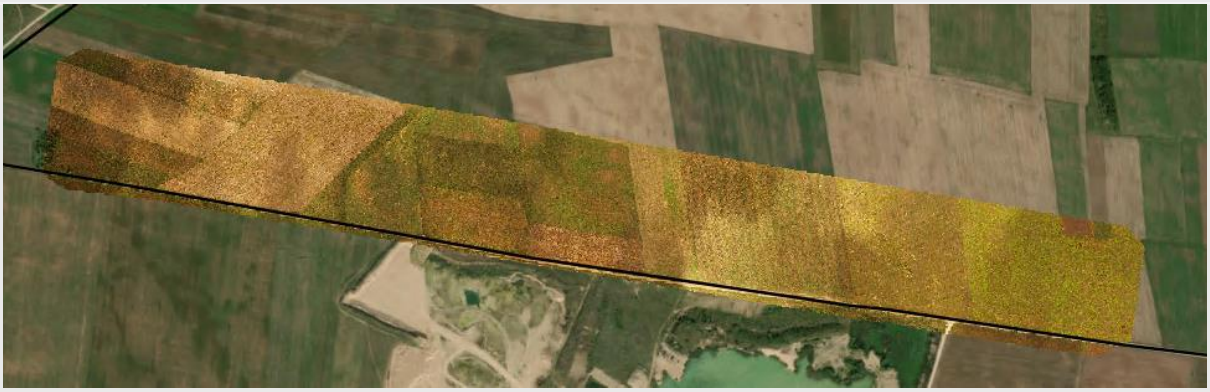
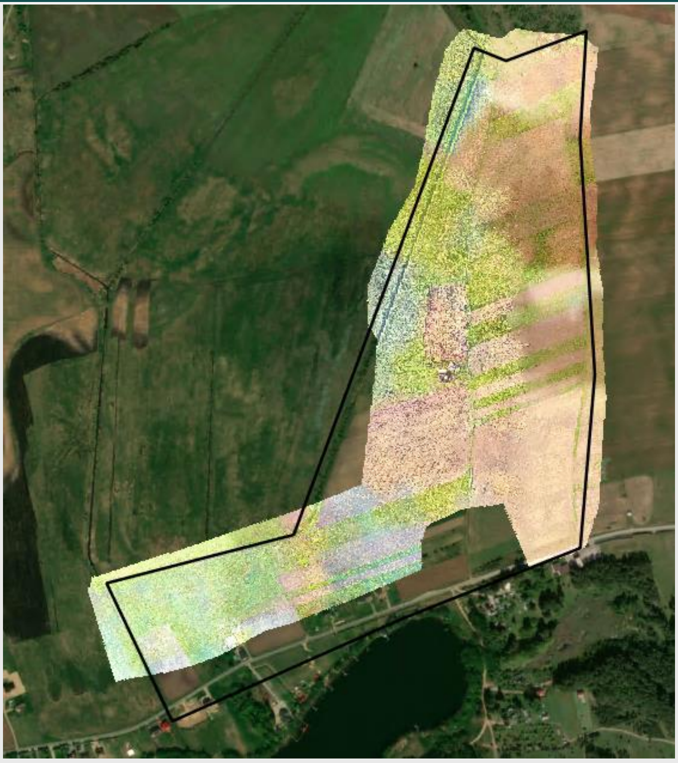
1st flight 24-27/5/2021	
2nd flight 26-29/7/2021	
3rd flight 13-16/9/2021	

Table 16: The generated image orthomosaics in the AOI 2.

Generated VHR orthomocaics: AOI 2	
1st flight: 24-27/5/2021	2nd flight: 26-29/7/2021
	
3rd flight: 13-16/9/2021	
	

5. Evaluation procedures

5.1 Preliminary control checks in the generated products

After the implementation of the drone flights preliminary qualitative evaluations were performed in the field to ensure the good quality of images, absence of "burn or destroyed images", including also the existence of the corresponding metadata file that includes the related geographic information (i.e. coordinates, projection system, etc.). This file in EXIF format verifies that every image contains its geolocation coordinates and the image is georeferenced. To implement the second step, the user imports all the images in the Agisoft Metashape software the relevant point cloud is presented as it is depicted in Figure 11. Furthermore, during the data collection process, the images are frequently stored in order to prevent any data loss of the collected data. This way, 2 sim cards with 64GB each were included in the android mobile phone, where the flight missions were performed.

5.2 Quantitative evaluation on the georeferencing

After the generation of the image orthomosaics for every scheduled drone flight campaign, a quantitative evaluation assessment procedure was designed, aiming to validate the horizontal and accuracy of the products and therefore to ensure that the VHR images will be exploitable products for time-series models that are deployed in the context of EO-component's marker services. The quality assessment of the compiled orthomosaics is implemented following the promising results of Ludwig et al. [4], who evaluate and reproducibility and validity of orthomosaics' time series, following two steps, (i) The evaluation of the positional accuracy using the checkpoint error, and (ii) the evaluation of the reproducibility error using the pixel-wise correlation coefficient metric.

Regarding the first step, a part of the total number of the GCPs that were gathered during the field campaigns and not used during the orthomosaics generation -with the training/test analogy of 70/30 – is utilised so as to enable the evaluation of the positional accuracy, acting as "independent observations". After the extraction of the orthomosaics the horizontal geolocation accuracy was implemented using the mean Checkpoint root mean squared error (i.e. checkpoint error, Equation (1)), with the XY_{test} to be the coordinates of the reference GCP and the XY_{train} the predicted coordinates extracted from the constructed image orthomosaic.

$$Checkpointerror = \sqrt{mean((\mathrm{XYtest} - \mathrm{XYtrain})^2)} \quad (1)$$

The aforementioned equation was calculated using the Euclidean distance between the points, used for the validation process. In specific, for every GCP, a point pair were compared, with the one to denote the coordinates that were manually extracted from the image orthomosaics, and the other the corresponding ground truth GCP received by the the pilot partners (CAPO, NPA). For the calculation to be complete, we need the coordinates of all GCPs in the same format, and thus a geographic projection of both points in WGS84 (decimal degrees) was chosen. From QGIS software the coordinates can be extracted easily by selecting a point and choosing which coordinates to copy. Finally, the Euclidean distance between the points was calculated by using the distance.distance() function located in the geopy Python library.

The second step of the process aims to measure the level of similarity between a pair of orthomosaics. In this context, two segments from orthomosaics generated between the drone flight campaigns are utilised and for each pixel, the cross-correlation was calculated using the scipy Python library and the correlate 2D function[14]. Pixels with high positive correlation values (>0.90) indicate that the RGB values are characterised with great similarity and it is more probable for the image pairs to have a pixel-to-pixel georeference accuracy. This process can be suitable only for permanent structures, such as roads since the crops are captured at different phenological stages and while facing different agricultural procedures, i.e. mowing, harvesting, ploughing, etc., between the three campaigns in each country.

The produced results from the orthomosaics assessment will be provided in the context of deliverables D6.2 and D6.3 that will cover the results from the deployment of the different DIONE toolbox components in Lithuania and Cyprus pilot sites respectively.

5.3 Challenges and applied solutions

During the performance of the experimental drone flights, two artefacts were identified with the first to be related to camera adjustments, and the second to the weather conditions and their effect on image quality and different lighting conditions in the drone orthomosaics. Both of them refer to artefacts that impacted the image quality. An additional challenge that is reflected in the generation of an accurate orthomosaic is that some images could not be aligned with other ones. So, some nearby images were separated into different chunks (in the Metashape software), they were aligned and later they were joined with the rest of the image set. In this case, a visual inspection process and manual corrections in the contained images in the chucks were performed.

Referring to the first artefact, in general, the digital cameras of drone has been designed to capture photos with natural lighting conditions and with cloudless weather[15]. However, in real operations, we assume that these conditions might change, for example, due to sudden cloud presence or as a malfunction of the drone operation software. This can be described as a malfunction to the “white balance” parameters and it is characterised by a misinterpretation of the camera’s light colour in the scene. The false colour illustrations can be seen through the presentation of the image with warmer or cooler colours. This way, it is commonly suggested to check and/or update the white balance settings before starting the flight operation, and ideally to perform these controls in every drone flight mission. Through the DJI Go application, the drone operator can define the white balance’s setting following two options, automated calibration and manual calibration. The automatic white balance has the ability to change the colour interpretation setting during a flight mission and calibrate the camera according to the present lighting conditions. In the customised definition, the temperature value can be set[16,17]. In our case, the automatic option was selected following the notion that is unrealistic to have the same weather during a flight mission. However, even in this mode, there were cases were the calibration wasn’t successfully performed, and as a result, some photos were captured with cooler colour interpretations. Figure 21 depicts the result of such cases.

As this artefact cannot be seen during the drone flight mission, post-processing histogram matching approach was applied [5]. In image processing, the histogram matching or histogram specification is the transformation of an image so that its histogram matches the suggested one[18]. In general, an image histogram indicates the intensity distribution of an image. In other words, the image histogram

[14] https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.correlate2d.html

[15] https://www.dronezon.com/aerial-photo-and-video/aerial-photography/best-white-balance-settings-for-aerial-photography/

[16] https://www.dronegenuity.com/manual-white-balance-drone/

[17] https://www.cambridgeincolour.com/tutorials/white-balance.htm

[18] https://en.wikipedia.org/wiki/Histogram_matching

shows the number of pixels in an image having a specific intensity value, with these values to be ranked between 0 and 255. In our solution, first, we had to identify the images that were characterised by this artefact and a neighbouring image with a normal colour representation. The histogram matching approach was performed with the assignment of the well-defined histogram to the respective falsely illustrated images. Figure 21 depicts the results after performing the image colour correction.

Figure 21: Left-side images indicate the false definition of the white balance effect; Right-side images are the colour corrected image after the conduction of the histogram matching approach.

Further to the above, during the drone flights, there were times that the weather conditions were unsteady with a significant wind intensity, producing a blurring effect in some drone images. Such cases can cause essential deviations in images' quality as characteristics over the scene are deteriorating, and therefore the advantage of the VHR images to recognise small objects in the filed. The abovementioned effect created also challenges in accurately denoting the GCPs' coordinates in the center of the ground markers that could deviations during the construction of the image orthomosaics. Examples of the above cases are presented in the figures below (Figure 22 and

Figure 23).

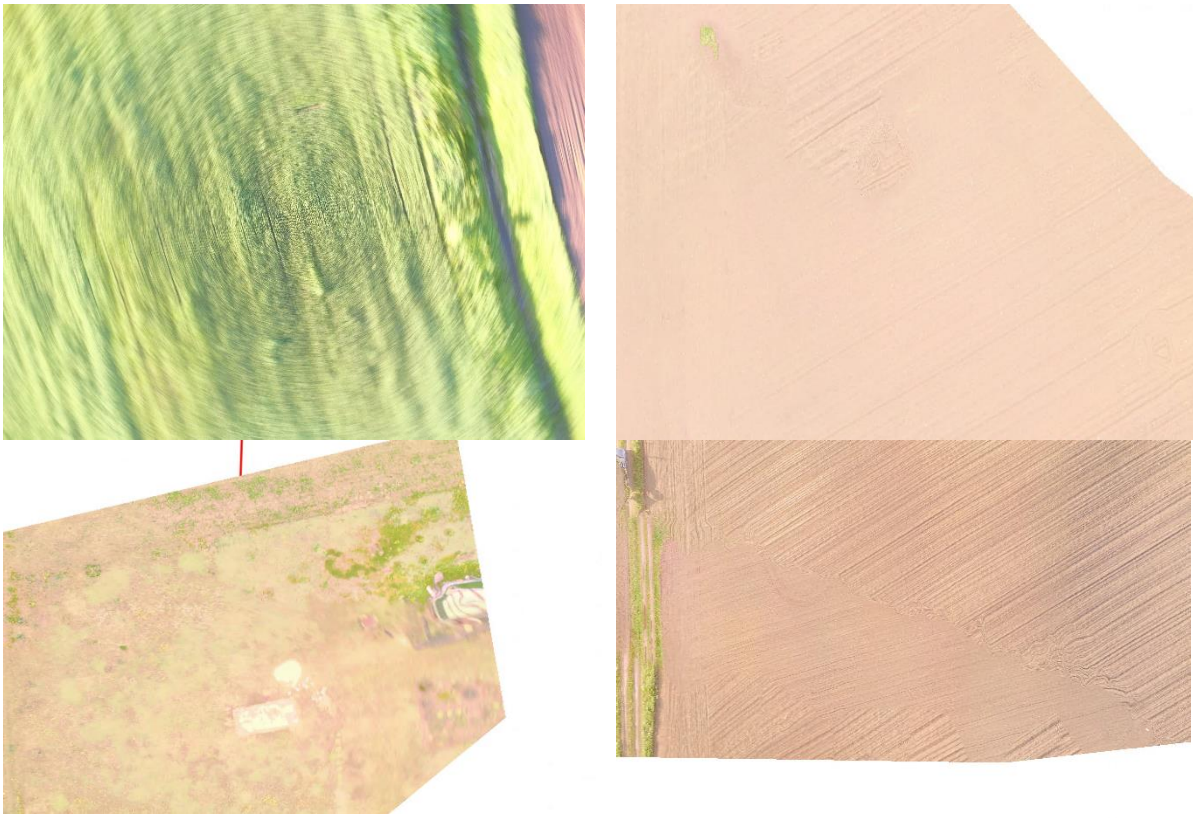


Figure 22: Left-side image: Examples of blurred images

Figure 23: The left image presents a case in one of the Lithuanian drone flight campaigns, in which the markers cannot be used in the calibration process of the image orthomosaic as the center of the marker is not visible and the collected GCP cannot be placed correctly. The right image presents a photo over the same case where the marker can be recognised.

In order to address this problem, different approaches were investigated, following the assumption that images with high detail and quality present more sharp edges and intense image values. Under this notion, the identification of "problematic" photos and their exclusion from the process of the orthomosaic generation could be achieved. In general, a wide variety of algorithms have been proposed for image blurring identifications and classified into seven categories, (i) the edge sharpness analysis, (ii) the low depth of field image segmentation, (iii) blind image deconvolution, (iv) Bayes discriminant function method, (v) non-reference block, (vi) lowest directional high-frequency energy and (vii) Wavelet-based histograms and support vector machines, with the first one to be suggested in agronomic and environmental applications [5]. For our case, an automatic image blurring detection concept was attempted, applying the two algorithms of Fast Fourier Transform (FFT) and the Laplacian-based operation. Further details can be found in Ribeiro-Gomes et al. [6] and Pertuz et al. [7]. In both operators, a "blurred image" is denoted when its resulting values are significantly low. Nevertheless, these operators weren't able to identify the blurred images as their FFT and laplacian scores weren't low enough to determine their lower quality status. This phenomenon occurs because in most cases, part of the image or a small segment of it was affected by this effect. As a final solution, these images were identified and excluded based on the manual process of visual inspection within the environment of QGIS.

6. Integration with EO component's data processing cycle

The deliverable 3.4 (D.3.4 DIONE EO component software prototype) showcased the different operational blocks that were responsible for harvesting, transforming, and uploading the super-resolution data. However, the uploading system was built under a generalised concept of transforming and uploading every EO data including as well the RGB-orthomosaic images that were generated from the drone flight missions. Following the same rationale that was depicted in D3.4 and illustrated in Figure 24, when the orthomosaiced image is generated, is stored in a dedicated folder for the images of Cyprus and Lithuania. A standardised filename prefix was determined, having the datetime of the image acquisition at the last part of the image filename. Formulating this, the proper folders in the cloud repositories and the tiles generations in the created data collections could be implemented.

Afterwards, as it has been described the proper image transformations of i) image unstacking and ii) conversion to Cloud optimised GeoTIFFs (COGs) are performed for the first level of upload in Amazon's cloud storage of Simple Storage Service (S3) bucket. Eventually, HTTPS POST requests are performed to ingest the data to the Sentinel Hub's (SH) data collections using the Bring-Your-Own-COG (BYOC) API. The whole is enriched with the time scheduler functionality, enabling the automated activation of this processing chain in case any new image is stored in the determined folder. Since the user has authorised/authenticated access in SH's modules and the single ID of the data collection, access to the images can be achieved. This way, the drone images can integrate into the EO component's products and in specific in the super-resolution model and the updates of the marker maps (e.g. EFAs detection).

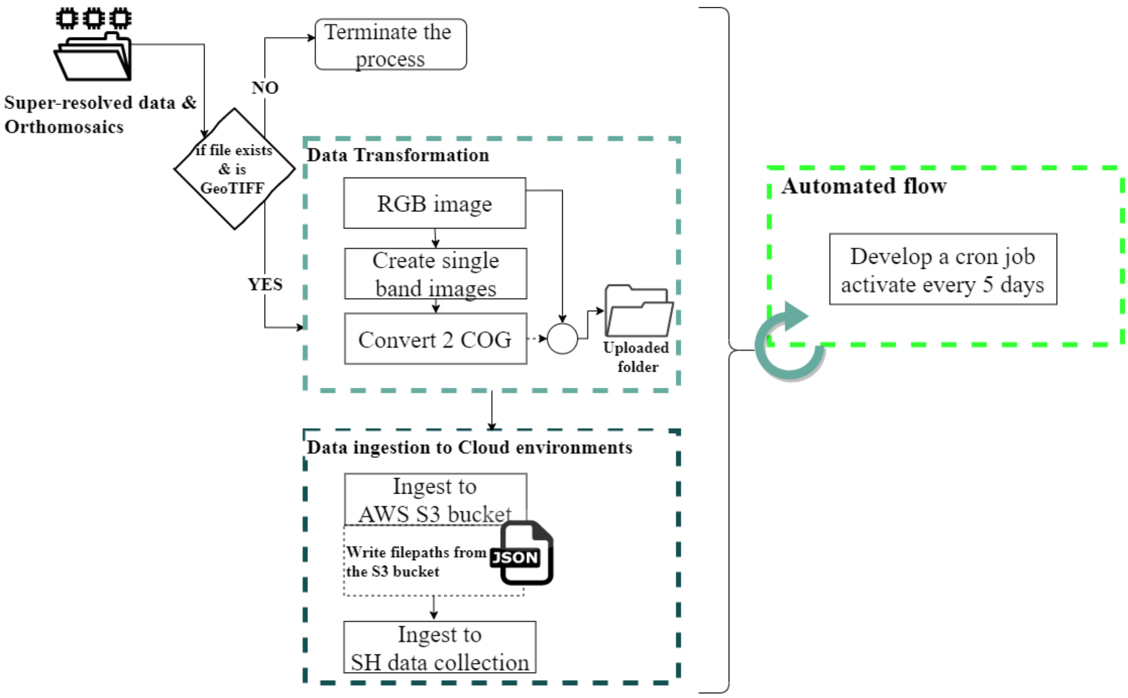


Figure 24: High-level architecture of the different processes that are taken place in the uploading operator.

7. Compliance with requirements/specifications

All the aforementioned procedures that were described in the previous chapters were designed under the frame of addressing the requirements and specifications for the usage of the drone-related products and tools, which were shown in deliverables *"D2.1 DIONE stakeholder list, personas and co-designed scenarios" and "D2.2* DIONE toolbox specifications and software architecture". For the drone flight products, the corresponding requirements are depicted in the following table.

Unique Id	MVP	Description	Means of verification
SYS_F_DRONE_1	UR_C16	The designed Unmanned Aerial System (UAS/UAV) should collect very high-resolution drone RGB images (lower than 0.5m) as well as corresponding exterior orientation (GNSS/INS positions), metadata, etc.	Achieved - To implement the drone flight campaigns and generate VHR drone data, the UAV platform is constructed by the following components, i) an unmanned quadcopter drone with the ability to receive the following information, such as i) GNSS/GPS receiver, ii) georeference, iii) extraction of georeferenced images embodying the exterior information of each image as *.EXIF format, etc. ii) a pilot remote controller assisting the operator with the navigation and remote communication, and iii) two software the DJI Go app, Ctrl+DJI plugin and the Pix4Dcapture handling the specific mission flight planning. Subsequently, using a VHR camera (pixel size 0.22m) along with the gimbal the UAV can capture the monitored area, ensuring the stability of the drone, e.g. in case of windy weather conditions.

SYS_F_DRONE_2	UR_C17, UR_S31	Generation of RGB orthomosaics	Achieved - As it can be seen in chapter 2.1.2, a well-structured processing flow was synthesised for the 3D model construction and the regeneration of the VHR RGB orthomosaic images. For this process, the collected images along with the generated metadata (.EXIF file) were used, whereas for the construction of the orthomosaics, the Agisoft metashape software, seemed the most suitable choice. Several preparatory checks were performed related to the calibration of the drone camera and the quality of the collected drone images, which ensured the provision of an accurate product. Subsequently, greater positional accuracy in orthomosaics was achieved during the aerial triangulation process by using the collected GCPs from on-the-field GPS measurements. Additional checks were also performed to evaluate the accuracy of the georeferencing procedure.

8. Conclusions

The document aims to provide a detailed view of the implemented drone/UAV platform and its deployment in selected regions in Cyprus and Lithuania and the generation of VHR orthomosaics that will be used by the DIONE EO component (i.e. data fusion algorithms and the identification of small-size objects in the crop fields (e.g. EFAs)). Various parameters were considered in order to implement successful campaigns, such as the selection of proper areas of interest based on their diversity in crop types and the existence of the EFAs, the specific dates of repetitions being aligned with the period of the CAP compliance on the field checks, as well as the local restrictions that occur since the beginning of 2020 due to COVID-19 pandemic. Besides the definition of the aforementioned, which was a collaborative work among the pilot partners (i.e. CAPO and NPA), a dedicated work was accomplished for the evaluation and the update on the UAV platform and its software and hardware components, aiming to apply a scalable procedure that could be performed in any similar case.

Furthermore, the conduction of the drone flight campaigns is presented, along with the procedure to collect GCPs that are essential in order to receive highly accurate orthomosaics. Respective evaluation procedures were explained relevant to the quality of the images and the accurate geolocation of the generated orthomosaics, addressing at the end the challenges that occurred during the campaigns and the methods that were applied to mitigate them. Further details regarding the evaluation of the results of all the orthomosaic products and their applicability in terms of accurate estimation of the marker maps will be given in the upcoming deliverables 6.2 and 6.3, aiming to report the demonstration of the whole DIONE solution in the two pilot cases of Cyprus and Lithuania.

9. References

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[7] S. Pertuz, D. Puig, and M. A. Garcia, "Analysis of focus measure operators for shape-from-focus," *Pattern Recognit.*, vol. 46, no. 5, pp. 1415–1432, 2013, doi: https://doi.org/10.1016/j.patcog.2012.11.011.

10. Appendix

Table 17: Different viewing angles of the digital surface model in the Choirokoitia area, visualising the variations in the terrain of the area in different segments of the AOI.

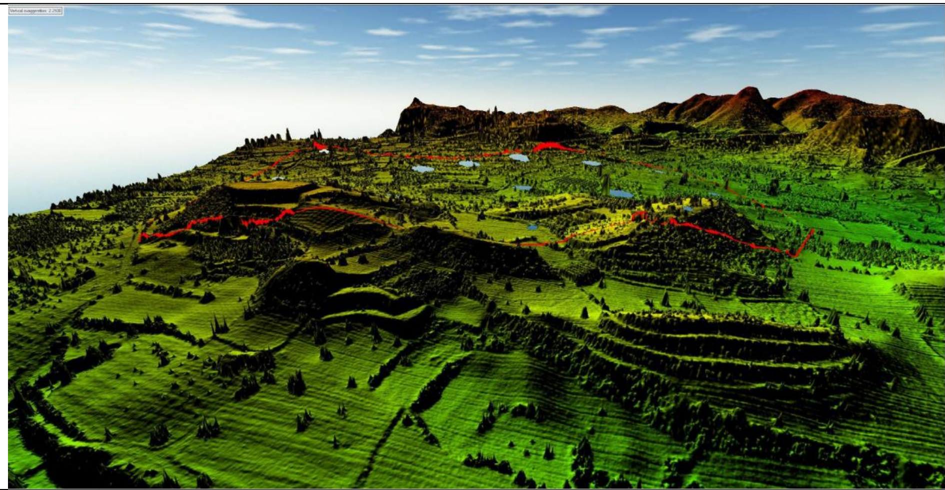
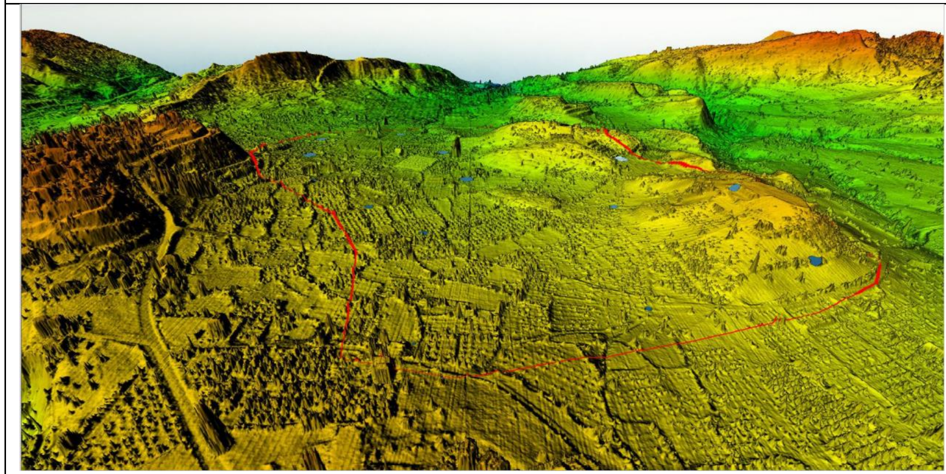
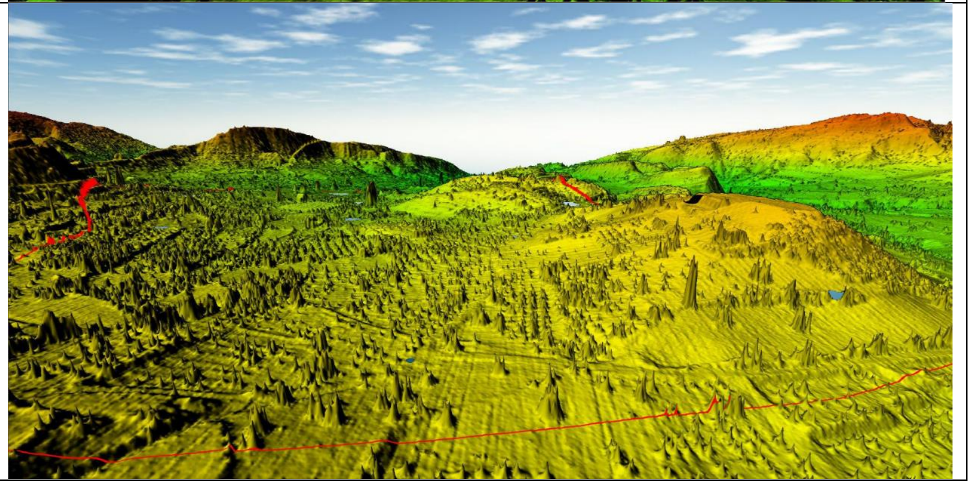
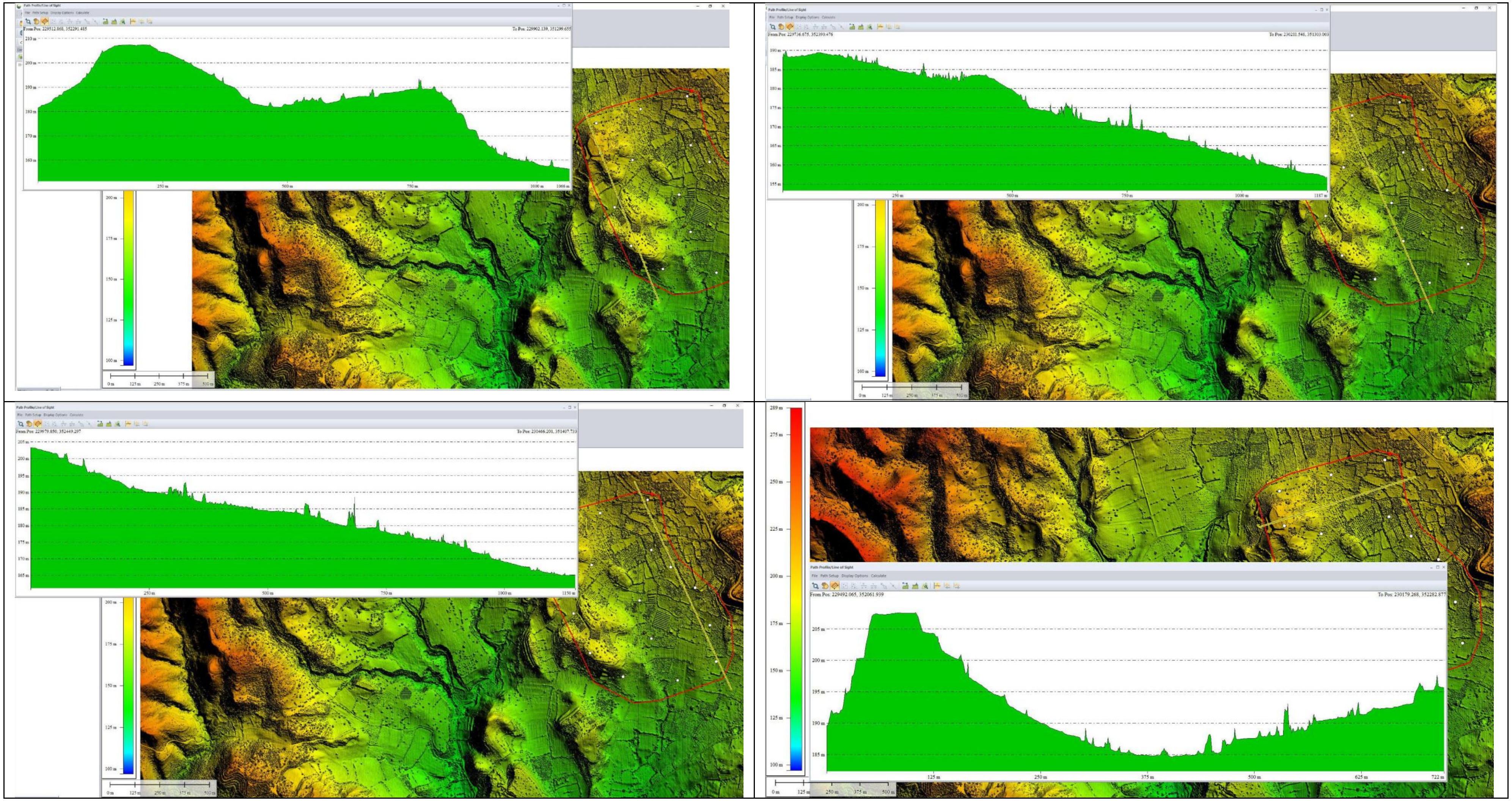
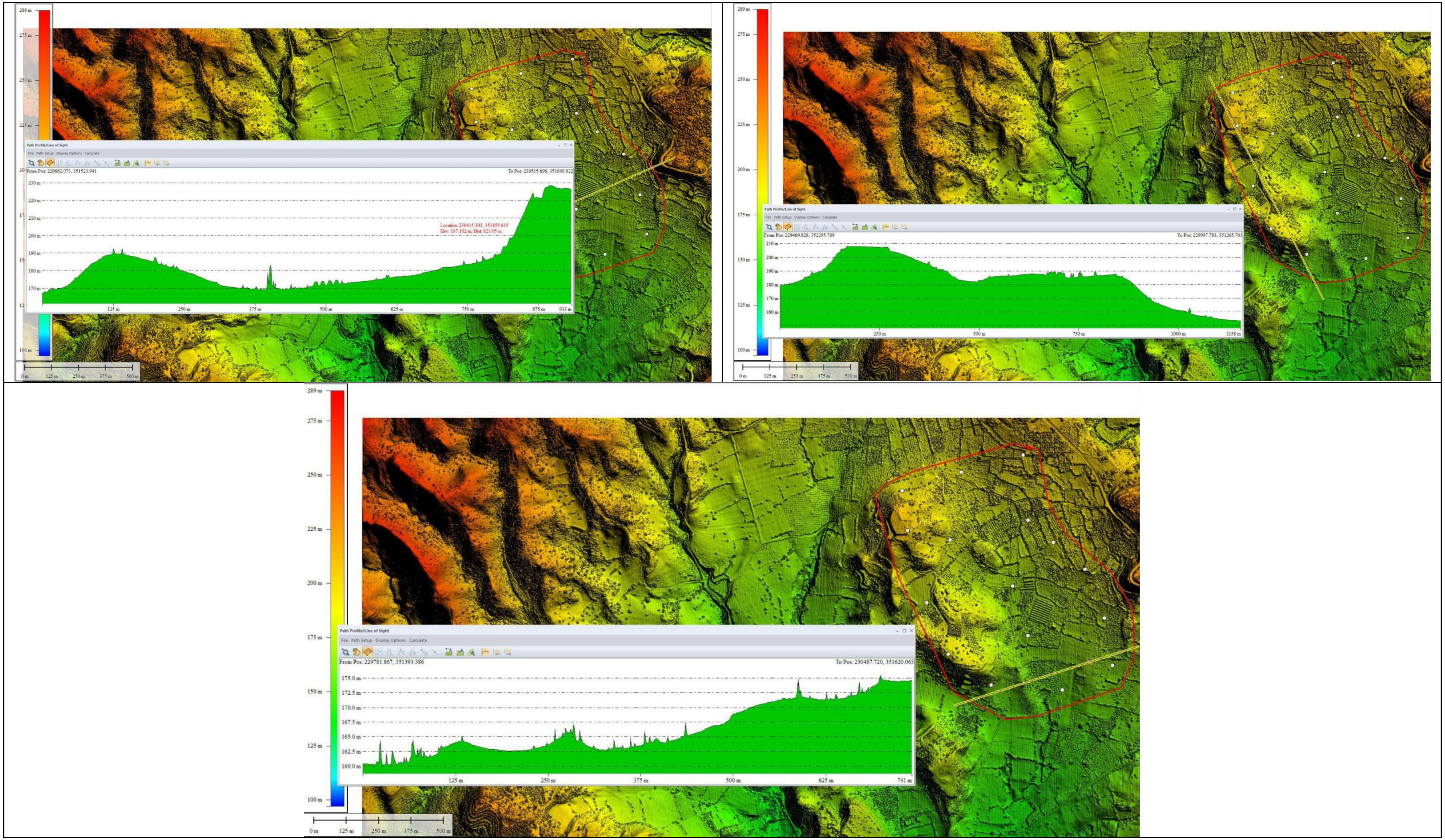
	
	

Table 18: Reflecting horizontal and vertical altimetric inclusions of area observing the changes of the terrain of the area.




Path Profile/Line of Sight
File Path Setup Display Options Calculate
From Pos: 229781.867, 351393.386
To Pos: 230487.720, 351620.063
175.0 m
172.5 m
170.0 m
167.5 m
165.0 m
162.5 m
160.0 m
125 m
250 m
375 m
500 m
625 m
741 m
200 m
175 m
150 m
125 m
100 m
0 m
125 m
250 m
375 m
500 m